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J. F. KELLY, Editor

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Coming Meetings and Papers

PITTSBURGH DISTRICT SECTION

Saturday, March 23, 1929 — William Penn Hotel

"SHORT CIRCUIT STUDY APPLIED TO A STEEL PLANT POWER SYSTEM," by R. M. Hussey, Electric Engr., Jones & Laughlin Steel Company, Aliquippa, Pa.

Synposis

Description of Power System as it was prior to 1923.
Description of Power Failures and Troubles Experienced Prior to 1923.
Description of Data for First Short Circuit Study.
Resume of First Short Circuit Study Report and Conclusions Drawn Therefrom.
Description of Revamping Work Done in the Period 1923-1926, inclusive.
Description of Changes Made in Power System Characteristics, 1923-1926, inclusive and compilation of New Data.
Description of Second Short Circuit Study.
Resume of Second Short Circuit Study Report and Conclusions Drawn Therefrom.
Description of Power Transmission System Layout at Present.
Resume of Power Failure and Trouble Reports Since First Item in Revamping Work Program Was Completed in 1924, Up to Present Time.
Some Probable Considerations for the Future.
Discussion of this paper by Mr. A. C. Cummins, Elec. Supt., Carnegie Steel Company, Duquesne, Pa.; Mr. B. M. Jones, Equip.-Protec. Engr., Duquesne Light Co., Pittsburgh, Pa.; L. A. Terven Technical Engineer of the West Penn System; Mr. G. P. Wilson, Genl. Engr. of the Westinghouse Electric & Mfg. Co.; Mr. A. G. Darling, Transmission Engr. of the General Electric Company and other Industrial Engineers interested in the Transmission of Electric Power.

PHILADELPHIA DISTRICT SECTION

Saturday, April 6, 1929 — Engineers' Club

General Ideas and Discussion

"ELECTRICITY A FACTOR IN REDUCED ROLLING COSTS, C. M. Thompson, Plant Engineer, Henry Disston Sons, Inc., Philadelphia, Pa.
"SMOKE ABATEMENT IN THE STEEL INDUSTRY," Martin J. Conway, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.
"POWER ECONOMY," R. M. Fuller, Consulting Engineer, Riverton, New Jersey.

CHICAGO DISTRICT SECTION

Inspection Trip to Crawford Station of the Commonwealth Edison Company

PAPER

"THE INTERCHANGE OF POWER BETWEEN CENTRAL STATIONS AND STEEL PLANTS," R. F. Schuchardt, Chief Engineer, Commonwealth Edison Co., Chicago, Ill.
Members and visitors will be guests of Commonwealth-Edison Co.

BIRMINGHAM DISTRICT SECTION

COMBUSTION MEETING

Saturday, March 30, 1929

"DISCUSSION OF THE STEAM EQUIPMENT OF THE FAIRFIELD WORKS OF THE TENNESSEE COAL, IRON AND RAILROAD COMPANY," J. M. Sprague, Steam Engineer, Fairfield Works, Tennessee Coal, Iron and Railroad Company.

CLEVELAND DISTRICT SECTION

Tuesday, March 19, 1929

"STATUS OF PLANT ELECTRIFICATION UP TO THE ENGINEERS AND SERVICE MEN," R. R. Rogers, Industrial Engineering Dept., General Electric Company, Schenectady, N. Y.

EDITORIAL

A MESSAGE TO THE MEMBERSHIP

of the

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS

Dear Member:

Your Convention and Exposition being held June 17th to 21st, 1929, at Pittsburgh, Pa., bids fair to be one of the epochs of our Association's History.

Your National Committees are functioning splendidly and they are busily engaged in the preparation of data for presentation at the technical sessions at the Convention. In this connection, questionnaires are being circulated throughout the Iron and Steel Industry requesting information and data for use in reports and we kindly ask that you lend us your aid and assistance and forward us the information desired.

You realize, of course, that we are the recognized engineering authorities in our industry and in order that we render the service expected of us, we must, each one of us, contribute our share.

Your Iron and Steel Exposition will this year be on a par with any similar event held in the United States, the representative manufacturers of equipment used in our Industry are all lending us their enthusiastic support. Many interesting features are being prepared for your inspection and the latest developments in the various arts will be shown.

All of the papers will appear in advance in the June Number of the Iron and Steel Engineer as well as the program of the Convention, the list of Exhibitors, the events in connection with the Iron and Steel Exposition, the Inspection Trips, in fact, everything in connection with your Convention and Exposition.

If you desire extra copies of the June Number of the Iron and Steel Engineer please forward your requirements now and we will be glad to take care of your wishes.

Your suggestions for a successful Convention are being solicited at this time.

C. S. PROUDFOOT, President,
Association of Iron and Steel Electrical Engineers.

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Symposium
Carbon Brushes

Presented Before Pittsburgh District Section Association of Iron and Steel Electrical Engineers, November 17, 1928.

Carbon Brush Standardization

By F. W. Cramer, Chief Electrical Engineer, Republic Iron and Steel Company, Youngstown, Ohio.

Carbon Brush Standardization as Viewed by a Designing Engineer

By A. M. MacCutcheon, Engineering Vice President, Reliance Electric and Engineering Co., Cleveland, Ohio.

Factors Affecting the Application of Carbon Brushes to Direct Current Motors

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Carbon Brushes for Motors and Generators

By G. M. Little, Research Laboratory, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Discussion

J. Ulvad, Chief Engr., Otis Elevator Company, New York, N. Y.

A. J. Standing, Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.

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J. H. Albrecht, Pittsburgh, Pa.

A. W. Mohrman, Elec. Supt., Follansbee Bros. Co., Follansbee, West Va.

Carbon Brush Standardization

By F. W. CRAMER

The attention of our Association has often been called to the enormous number of different carbon brushes that have to be carried in electrical storerooms to fill the requirements of the various motors. The absurdity of having several hundred different brushes in use has been realized by our engineers for some time. Yet, the Steel Industry representing only a small minority of the total motor users, did not feel that it was the duty of the A. I. & S. E. E. to attempt to solve the problem of brush standardization. As individuals, however, we realized that an inventory showing four or five hundred different carbon brushes was hard to explain and also a useless burden to carry, so in many of the plants individual efforts toward brush standardization were started. The results of these individual efforts were so encouraging that the Association felt it could assist in this work if a meeting was held in which the motor designers, the motor builders, the motor users, the brushholder manufacturers and the carbon brush makers were all invited and all given an apportunity to give suggestions on how the myriad of different brushes now required could be reduced in number.

We all realize that good design and performance of direct current motors and generators requires several grades and sizes of brushes. But we also realize that there is no real necessity for every dimension possible in width, breadth, length, height and the degree of bevel. These physical variations in turn require a corresponding number of different brush holders which add their problems to the inventory details. We also realize that the great variety of pigtail mountings and clips are uncalled for. It has further been proven on many occasions that the special grade of brush used to solve a commutation problem has been needed only because of an error in design or manufacture of the machine. Nevertheless we realize that there is some minimum number of brush sizes and grades that are required on a line of motors and generators from the smallest to the largest and there may be some good reasons for having several ways of attaching the pigtails and perhaps a few different sizes of clips. These, however, are problems which rest with the designer and we hope will be discussed in the papers.

It seems reasonable that the proper place to start our investigation of this subject is with the designer of the motors or generators and learn from him his limitations and demands, for we realize that the brush manufacturer and brush holder builders have to furnish the products called for by the motor producers. Then we can hear the brush and brush holder makers' side of the story which will show the unlimited variety of grades, shapes and sizes actually in use. And finally the brush users—the steel mill electrical men who have to pay the bill and be responsible for the storeroom stock of spares —can give their side of the case.

Speaking as one of the latter class, I would offer a few suggestions that have already been tried out in our mills. The first is a survey of the number of different brushes in use arranged in classes as to grade, width, length, height and bevel. This possibly will show several similar brushes with the difference in how the pigtails are put on and the type of clip. You can determine how many of these are unnecessary. The different heights having the same width, breadth and bevels offer a further chance of reduction. Then the grades can be reduced in number by finding the modern grade that superseded the ones used on the pre-war motors. A study of this sort reduced the number of different brushes used by over 100 in one of our plants.

Another suggestion is for the motor manufacturers to create a method so that we will know what brush is to be furnished on the newly purchased motor. This is one of the details that seldom appears in the motor specifications and it has often happened that for good reasons the manufacturer has changed brushes on a motor without the purchaser's knowledge of the change. When expecting a duplicate motor of one already in use such changes are sometimes troublesome.

There seems to be an unlimited field for discussion on this subject and the records of this meeting should furnish the basis for a start in the steel industry of a material reduction in the myriad of different carbon brushes now required in the operation of steel mill motors and generators.

One of the landmarks of the A. I. & S. E. E. is friendly co-operation with designers and manufacturers. This trait has enabled the electrification of mills to attain the magnitude it enjoys at the present time. This problem of brush standardization will enjoy the same reception that mill motors, cranes, etc., have in past deliberations. With a feeling of this sort acknowledged by the designers, makers and users, carbon brush standardization in the steel industry should not be difficult to solve.

Carbon Brush Standardization as Viewed by a Designing Engineer

By A. M. MacCUTCHEON*

NO one, whether he be a designing engineer or a user of motors, can question the great advantage and desirability of standardization. Standardization has very definite and easily seen advantages. It should also be recognized that there are certain inherent disadvantages in standardization. It is the engineer's function to take those materials which nature and human ingenuity have provided and apply these materials in the best way to accomplish certain desired results. It seems almost self-evident that the less an engineer is hampered by standardization, the better results he will secure in any particular case. On the other hand, under such a procedure, the higher will be the cost of original manufacture and the higher will be the cost of maintenance. Securing the proper degree of standardization, carefully considering all factors, therefore becomes one of the most difficult and highly specialized phases of engineering. It therefore seems to me that the proper attitude of an engineer toward standardization is to recognize its unquestioned advantages, and also recognize its unquestioned limitations, reaching the best balance between these two opposing conditions.

I have no doubt that it often seems to the users of manufactured apparatus that the manufacturer pays little or no attention to the question of standardization, but a little consideration on your part will enable you to see that it is almost as much to the advantage of the manufacturer as it is to the advantage of the user to secure the maximum degree of standardization consistent with other considerations. Inventory is decreased, lessening the manufacturer's investment; quantities are increased, lessening the cost. Both you and the manufacturer recognize that many secondary factors enter into a large and varied stock, as for example, the providing of an increased number of stock bins, the handling of and keeping separate the different items, the clerical work involved in keeping track of these different items, and the difficulty of selecting the proper item for a particular case.

It seems to me that the following are the principal factors entering into selection of a brush by the designing engineer:

1. The type of brushholder to be used.
2. The grade of brush to be used.
3. The thickness of the brush.
4. The width of the brush.
5. The length of the brush.

The following minor points have not been listed as entering into the selection of the brush since, while they must be considered, they are not such determining factors as the ones already mentioned.

1. The angle of the brush to the commutator.
2. The type of brush shunt to be used.
3. The size of shunt.
4. The length of shunt.
5. The method of fastening the shunt.

Considering somewhat in detail these major points listed, we will take for our first consideration the type of brushholder to be used. There are certain advantages in having the brush radial with respect to the commutator. Operation is then equally satisfactory in either direction. On the other hand, radial brushes are much more likely to chatter than a brush that is set at some angle to the commutator. Personally, I believe that a brush at an angle of about 15° to the commutator just meets all conditions. There are certain advantages and disadvantages to what is known as the reaction type of brushholder. There are certain advantages in fastening the brush directly to the brushholder so that part of the brushholder moves with the brush. There are certain disadvantages to a box surrounding the holder, which disadvantages may be overcome in the use of a reaction type holder or a brush fastened directly to the holder.

It is not my purpose tonight, to enter into a discussion of the relative advantages and disadvantages of different types of brushholders, but only to point out that the designer must consider the type of brushholder which he is going to use and further, to have you see that the brush may be affected by the type of holder which is selected. If it were possible to standardize on the best type of brushholder to use, the standardization of brushes would undoubtedly be simplified.

May we now consider the grade of brush which is to be used? An ideal brush might be described as follows: A brush with no surface friction, one that does not have any wear, is without abrasive action, with a very high cross resistance and a very low longitudinal resistance. This perfect brush should be supplied with a shunt that does not deteriorate, never comes loose and has extremely high current carrying capacity. Excepting in very special cases, the perfect brush should have a fairly high contact resistance and a very high current carrying capacity. We recognize that it is impossible to make such a brush and that the brushes which are manufactured represent the untiring efforts of the brush manufacturer to as nearly as possible approach to this perfect brush. It is recognized that no one grade of brush can best meet all desired conditions, which automatically results in various grades of brushes to meet different conditions. The selection of a particular grade of brush is invariably a compromise and the designing engineer is always looking for something better. Motor designers, motor users and carbon brush manufacturers have repeatedly demonstrated that the grade of brush best adapted for certain motor-operating conditions, would not be the best grade of brush for another motor operating under different condition, nor even for the same motor operating under different conditions. I feel that I would like to very strongly state that my experience shows that industry has not yet

produced any grade of carbon brush best adapted for all different motors under all different operating conditions and therefore there is no grade of brush which can be considered a cure-all for all commutating troubles.

In selecting a grade of brush best adapted for a line of general purpose motors, the designing engineer will endeavor to secure a brush which has a low coefficient of friction, (a fairly high contact drop, a high cross resistance, a low longitudinal resistance,) a low abrasiveness with long life, has a high current carrying capacity and with a liberal shunt adequately secured. To meet the different operating conditions, in such a line of motors, say from 1 h.p. to 100 h.p., I believe the designer will be compelled to select three grades, although possibly this could be reduced to two.

With reference to the thickness of the brush, for a certain current, the thicker the brush the lower the current density and the longer the time in which commutation may be effected in an armature coil. On the other hand, if the brush is too thick, circulating current will result. The coil being commutated, will come under the affect of stray fields from the main poles during the period of commutation and glowing and pitting of the brush will result. In general, the thickness of the brush should not be greater than 25% of the inter-polar space referred to the commutator and possibly 20% is even better. With the changing diameter of the commutator over different sizes of motors, I feel that at least three thicknesses of brush are necessary for each size brushholder adopted. For example, in a certain size of brushholder used on motors from 5 h.p. to 35 h.p., it seems to be very desirable to have brushes 3/8 in thickness, 1/2 in thickness and 5/8 in thickness.

It is evident that the wider the brush the greater its current carrying capacity per brush. On the other hand for the same number of brushes per stud, the longer the commutator and the greater the cost of the machine. Neglecting the necessary clearances, it is obvious that a commutator for two 1½" brushes must be 3" long and for two 2" brushes, it must be 4" long. For one rating, two 1½" brushes may be entirely satisfactory but for another rating, two 2" brushes are necessary. If the two 2" brushes were used in both cases, unnecessary expense would be introduced into the commutator which is a very expensive part of a DC machine. For the best results, all things being considered, it would seem necessary to increase the brush width by 1/4". For example, with a brushholder used on motors from 5 to 35 h.p., it would seem necessary to have brush widths of 1, 1¼, 1½ and 2". If we might digress for a moment, it would seem as though the four sizes might be cut down to three sizes if there were a more logical increment in the width. 1¼" is a 25% increase over 1", 1½" is a 20% increase over 1¼", 2" is a 33% increase over 1½". A more logical increment might be the square root of 2 so that the brush widths would be 1", 1.42" and 2". With this increment, I think that three widths of brushes could well replace four widths which now seem to be necessary.

The length of the brush, radially, would seem to be a function of the size of brushholder. For a particular brushholder, the brush cannot be too long since the brushholder arm would not ride properly on the brush throughout its whole life. It is desirable to have that part of the metal arm which rests on the brush move in a radial direction with reference to the commutator. This is obviously impossible if the arm is pivoted. The longer the lever arm the more nearly this ideal condition is secured. With a small brushholder, it is obvious that the lever arm cannot be as long as with a large brushholder. It is also obvious that on a large machine, it is logical and possible to use a larger brushholder than on a smaller machine. Over a line of motors from 1 h.p. to 200 h.p., it would seem to be desirable to have at least three sizes of brushholders.

Reviewing all these considerations, it would seem to be necessary to have two types of brushholders as regards design,—in each of these types three grades of brushes to be called for. In each of these types and grades, three thicknesses would be necessary. In each of these types, grade and thicknesses, four widths would be required. In each of these types, grades, thicknesses and widths, there would be three lengths of brushes corresponding to different sizes of brushholders which would result in 216 different brushes to cover a line of motors from 1 h.p. to 200 h.p. made by a single manufacturer.

Practically, however, it is not necessary to have every one of these combinations to adequately cover such a line of motors as I have described, but the 216 represents the limit, assuming my assumptions to be correct.

You are undoubtedly very much surprised and somewhat staggered by the possible number of brushes from one manufacturer and we should carefully consider together the possibility of reducing our assumptions, with the consequent saving in the maximum number of brushes which would result.

I believe it is very desirable and quite logical for one manufacturer to confine himself to one type of brushholder. In fact, I have been informed that in England, many manufacturers have combined together on one type of brushholder, which is made by a company independent of the motor companies. This has resulted in great advantage both to the manufacturer and to the user. I believe that it should be possible for a manufacturer to confine himself over such a line of motors as I have mentioned, to not over two grades of brushes. I believe that three thicknesses are essential, that three widths are necessary and that there would be at least three sizes of brushholders. If these assumptions are correct, the maximum number of brushes would be reduced from 216 to 54.

While I hardly think it possible, it might be very desirable for the manufacturers of carbon brushes to endeavor to standardize on that grade of brush which is best adapted for a line of general service motors. I believe that the different conditions under which motors operate as regards speeds and loads, atmosphere, etc., have more to do with different grades of brushes being required than the inherent characteristics of the different lines of motors manufactured. I know that brush manufacturers would very much welcome the maximum degree of standardization possible as it would reduce their costs and make it possible for them to serve their customers among the manufacturers and users much more expeditiously and satisfactorily.

Brush manufacturers endeavor to as completely as possible give to the motor designers information as to the characteristics of the various grades of brushes. It would be very helpful if in addition to the information they are now giving, they could tell us something as to the relation between the cross resistance and longitudinal resistance of the different grades of brushes.

It should be recognized that considerable has already been accomplished on brush standardization. Ten years ago, a brush might have been taken from stock which was apparently of the right size and yet it would not fit in the holder. In those days, brushes were varying in thickness or width by thousandths. Pages 14 and 15 of the 1928 edition of the N.E.M.A. Apparatus Standards covers a considerable degree of brush standardization. It is there specified that the width of a brush from ¼" up to 2½" shall increase by steps of ⅛". That the thickness of brushes over ¾" increase in steps of ⅛". Tolerances are set up, certain standards are listed for screws and brush shunts. It is possible for this standardization to be carried even further, with a consequent benefit to the electrical industry.

I should like to close with a few comments on the care of motors with particular relation to the brushes and the commutator. Undoubtedly the majority of the electrical engineers of the steel mills present tonight know a great deal more about the proper care of motors with reference to these two points than I do but since it is a subject so important, both to the users and manufacturers of motors, I feel that every opportunity should be taken to place emphasis on this matter.

In general, commutators should be undercut. This has been a much discussed point but it is interesting to note that in many applications where flush mica was previously specified, such as elevators, this practice is changing. Trouble may result from undercut commutators but it is my belief that less trouble will result from undercut commutators than from mica. With undercut commutators, however, I feel it is necessary to occasionally clean out the undercut spaces if carbon dust or other material is accumulating. Such cleaning should be done about once a month at the same time that the brushes are inspected and replaced if necessary.

Brushes should always be ground in to fit the commutator upon replacement. It hardly seems necessary to mention this point and yet I have known of a great many cases where this has not been done. I recall one case where a complaint was made that the motor surged. All that was done to correct the difficulty was to grind in the brushes to fit the commutator and replace the neutral as it was when the motor was originally tested.

No oil or lubricating material should be used on the commutator. Here again it seems hardly necessary to mention this but I have ran into many cases in the last few years where this practice has been followed.

Brushes should be inspected at least once a month to make certain that they are free to move in the box if the box type holder is used. A great deal of damage can be done to a commutator due to a brush sticking in the holder and therefore arcing.

Tension should be rather carefully checked, at least once a month. Apparently, there is a great tendency to increase the tension of the brushholder spring whenever there is any sparking and to increase the tension to an abnormal amount. Many times the conditions are not improved at all by this increase in brushholder tension. I have known of cases where the surface friction was increased so much by increasing the tension that solder was actually melted out of the commutator tails due to the resulting heat, and decrease in brush tension was all that was necessary to cure the difficulty.

While commutator stones undoubtedly have their place to correct temporary difficulties, I believe it is much more desirable to secure a device for trueing the commutator without removing the armature from the motor. I also believe that it is cheaper. I have seen a man work for hours trying to take a flat spot out of a commutator by means of a commutator stone, whereas in half the time he could have installed one of these trueing devices and done an infinitely better job.

It is my sincere desire and I believe the desire of all designing engineers that further progress may be made on brush standardization with the consequent advantage both to manufacturer and the user

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Factors Affecting the Application of Carbon Brushes to Direct Current Machines

By C. W. LANGE

The determination of suitable brushes for a particular motor involves the selection of the three dimensions, the type of pigtail, the grade, and in the case of brushes operated at an angle also the bevel.

(1). Thickness of Brush

This dimension is usually selected first, based on brush overlap on the commutator, and brush thickness projected to the armature diameter in per cent of the distance between main pole tips. In order to avoid excessive short circuit currents in the brushes, this dimension should not be made greater than consistent with other factors. Some of these factors are of sufficient thickness to reduce the tendency to rock when reversing, and the chattering of radial brushes. Also, the projected brush thickness

is not used directly but must be modified by adding a slot pitch minus the projected width of one commutator bar, and in the case of fractional pitch windings, further allowance must be added to compensate for the amount of deviation from full pitch. This dimension usually permits of a slight latitude, and except in the case of very small brushes, usually varies in steps of ⅛ inch. It is customary to use a brush already developed if possible.

(2). Width of Brush

This dimension is determined by the factor of current density, and the watt loss per square inch of commutator face due to friction and contact resistance loss. If the commutator face has already been determined for a standard motor and a special rating is required, the brush thickness may be varied, and the width maintained the same if the commutator area is sufficient. This dimension usually varies in steps of ⅛ and ¼ inch. It is here also customary to use a dimension previously established if possible.

(3). Length of Brush

This dimension, on which the useful life of the brush depends directly, is made as great as possible consistent with the type and size of brush-holder and pressure finger used. It cannot be longer than will permit of its removal without removing the brush-holder, and should not be so long that the pressure finger will not rest properly on the brush. The length also should be such that the brush spring pressure will not vary too much throughout the life of the brush. This dimension usually varies in steps of ¼", although in some of the smaller sizes it may vary in steps of ⅛".

(4). Brush Pigtail

The cross-section of the pigtail is selected such that the current density in the pigtail does not exceed a limiting value. Since only a relatively few cross-sectional sizes of pigtails have been standardized, the choice is somewhat restricted. Where an abnormal and very stiff pigtail is indicated, double pigtails or a pigtail of special design may sometimes be used. The length is made long enough to permit removing the brush from the holder without disconnecting the pigtail, but should be short enough to prevent accidental grounding to the brush-holder support or frame. The length usually varies in steps of ½", except that for small brushes the steps may be ¼".

The type of pigtail fastening is determined by the kind of brush-holder used and by convenience.

(5). Grade of Brush

Usually one grade of brush is suitable for all sizes in a line of machines, although in special cases it may be found desirable from the standpoint of commutator limitations, very high speed, very high current, etc., to change the grade. However, it should be possible to limit the variety of grades considerably since the carbon brush manufacturers can provide a general purpose brush having the necessary characteristics for all but unusual conditions.

The following fundamental considerations in connection with the application of carbon brushes to direct current motors may be of interest:

Although in a non-commutating pole machine with fixed brush position at the mechanical neutral point, greater dependence for good commutation is placed on the criterion that the product of the contact resistance and the time of commutation divided by the inductance of the commutated coil shall be greater than unity, or that the brush contact drop for the commutated coil shall be greater than the average reactance voltage in the coil (i. e., the average rate of change of current in the commutated coil), than in the case of a commutating pole machine, nevertheless the consideration of similar factors is necessary for both types.

With a fixed brush position for reversible operation, and without a commutating flux such as is obtained by shifting the brushes into the flux fringe from a main pole of proper polarity or by means of commutating poles, the afore-mentioned criterion indicates that it is essential that the brush contact resistance be high, the inductance of the commutated coil be low, and the time of commutation as long as practicable (based on considerations such as brush overlap, number of coils per slot, and width of commutating zone). Consequently the quality of high contact resistance in a carbon brush is of paramount importance. Moreover, since the contact resistance decreases with an increase in current density and with an increase in temperature, the friction losses (dependent on the coefficient of friction in the brush) should be kept lower, and it is desirable to keep the current density in the brushes to a lower value than is permissible when a commutating flux is used.

However, even in the case of commutating pole machines, a certain amount of dependence is placed on the brush contact resistance, because the induced commutating e.m.f. is not of the exact wave shape to completely neutralize the self-induced reactance voltage in the armature coil, and due to the lag produced by hysteresis and eddy currents is not exactly in phase when the current varies suddenly. Also, on heavy overloads, due to saturation of the commutating flux circuit, the commutating flux may become deficient, and the difference between the commutating e.m.f. provided by the commutating flux and that required for good commutation is supplied by the brush contact resistance.

It is evident therefore that the ideal characteristics of a carbon brush are (1) High contact resistance for commutation, (2) High current carrying capacity for economy of design, (3) Low coefficient of friction for low friction loss, reduced heating, and economy of design, (4) Low inertia to insure the maintenance of good contact under the action of spring pressure when vibration is present, and (5) Long life for economy of operation. It is sometimes necessary to use a brush in which one or more of these characteristics are predominant at some sacrifice of the others, but often there are other factors in the design to partly compensate for the difference. However, the carbon brush manufacturers are approaching the ideal brush more and more, and progress has not stopped.

In order to prevent excessive circulating currents in the brushes with consequent heating, reduction in contact resistance, and possible sparking at the brushes, it is necessary to have the commutating pole flux as nearly proportional as possible to the armature current over a wide range, and to have it

change as nearly simultaneously as possible with the changes in armature current. For these reasons, especially in the case of machines subjected to heavy overloads and rapidly varying loads, commutating pole machines should be designed to obtain the following basic characteristics: (a) Low reactance voltage, that is low inductance of armature coils, since this requires less commutating flux and permits using the straight portion of the commutating pole saturation curve over a relatively wide range of load, resulting in a commutating flux proportional to load, a quickly responsive commutating field, and a minimum amount of commutating field copper. This desirable characteristic, so necessary in a direct way in the case of non-commutating pole machines, is thus seen to be important in a different way in the case of commutating pole machines. (b) Relatively low saturation of the commutating flux circuit. The importance of this is evident from a consideration of the reasons just mentioned. This characteristic of course does not apply in the case of non-commutating pole machines.

It sometimes happens that these desirable conditions cannot be achieved completely in a direct way, and resort is made to additional means such as laminated commutating poles to obtain a somewhat "faster" commutating field although the effect of saturation is not compensated for, or to an increase in the air gap reluctance (Straight line curve) by adding air gap or equivalent non-magnetic reluctance between the commutating poles and the magnet frame to obtain a straighter saturation curve throughout the load range and consequently a field more nearly proportional to the armature current and one having a quicker response to change. This arrangement necessarily requires the use of more copper in the commutating field coils.

As regards the question of brush standardization for machines developed subsequent to such standardization. I feel sure that the General Electric Company is willing to co-operate fully with the Standardization Committee of the A. I. & S. E. E.

Selection of Carbon Brushes

By G. WILLIAMSON*

MANY persons who have noted the great variety of sizes and grades of carbon brushes used on direct current motors and generators have expressed the thought that it should be possible to make a single material that would work on anything, so that a few sizes would cover the entire field. Up to the present time, however, this perfect brush has yet to make its appearance and we are forced to do the best we can with the closest approximation to perfection which we can obtain. While we cannot get a brush which will give ideal results on every type of apparatus, the brush makers have succeeded in giving us a variety of high grade materials from which a proper selection will afford good operation in almost every case.

A brush on a direct current commutator has, unfortunately, two entirely different and distinct services to render; first, the leading of current into and out of the commutator, and second, part or all of the job of reversing the current in the armature coils during the time they are short circuited by the brush.

Either one of these functions could be taken care of very easily by itself; it is the necessity for managing both at once that gives us the problem of brush application, and incidentally sets limits to the speeds and outputs obtainable with direct current apparatus.

If the brushes had only to collect current they could be made of low resistance, run at high densities, commutators could be made much smaller, losses would be reduced and efficiencies increased. In order, however, that the current in the short circuited armature coils may be reversed without arcing or sparking, the brush contact must have appreciable resistance, the amount of this resistance depending upon the magnitude of the short circuit voltage across the brush, a factor which cannot be entirely eliminated even with the most carefully proportioned commutating field.

Another feature of the ideal brush would be a zero coefficient of friction, to reduce losses and commutator temperature, and this is something with which no other requirements conflict, except in cases where a certain amount of cleaning action may be required.

In thus considering the qualities required in a brush, it is apparent that we are very fortunate in being provided with the element carbon, and that if this were taken away we would have to start all over again to produce workable direct current machinery. In its various forms and possible compounds it comes close to giving all the characteristics which we need, including conductivity, contact resistance, low friction and durability both as regards wear and high temperature or arcing, and is only fundamentally lacking in its possession of a negative temperature coefficient with the consequent tendency to uneven distribution of current between parallel brushes.

In deciding upon the brush to use on a given motor or generator we are usually limited to a certain extent by the desirability of conforming to a standard brush holder, a standard commutator face, a stock brush size and quality, etc. If it is assumed, however, that we are given a free hand in every respect, there are about a dozen distinct points upon which a choice may be exercised, as indicated in the following list:

A: Quality

1—Hardness.
2—Abrasiveness.
3—Specific Resistance.
4—Contact drop.

5—Coefficient of friction.

B: Shape

1—Rectangular a—Clamped type.
b—Sliding type.
2—Beveled a—Leading.
b—Trailing.

C: Size

1—Thickness.
2—Width.
3—Length.

D: Special Constructions

1—Different grades or different positions on each stud.
2—Toe of brush reduced in length—V grooves in brush.
3—Each brush divided electrically or mechanically.

Many of these items are of course more or less interdependent, as will appear in taking them up in order:

A: Quality

1—The hardness of a brush is the quality which principally determines its resistance to wear, and is rated in brush catalogues by Scleroscope readings. Other things being equal, the hardest available brush will naturally be selected, to give maximum brush life. It should be noted though that at high speeds a brush which is a little softer and less elastic will sometimes maintain better contact with the commutator and may therefore be preferable even at some sacrifice of life.

2—Abrasiveness is a quality entirely distinct from hardness, some of the softest brushes being at the same time very abrasive. To keep commutator wear to as near a negligible quantity as possible an absolutely non-abrasive brush should be used wherever feasible. No abrasive action should be needed if commutator is properly undercut so as to leave no mica slivers reaching the surface and if commutation is good. If service conditions or other reasons require flush mica, or if sparking or peculiar atmospheric conditions are such as to smudge or burn the commutator surface, then an abrasive brush must be used, but the less abrasiveness the better, as well to reduce friction, heating, and tendency to chatter, as to save the commutator from undue wear.

3—The specific resistance of the brush material determines the resistance to current flow and heating in the body of the brush as distinguished from that in the contact. The voltage drop in the substance of the brush is ordinarily so low compared with the contact drop that it is not as important as might appear in fixing the current capacity of the brush although in a few very high resistance graphite mixtures it does become the limiting factor. There have been numerous brushes developed with a cross resistance several times the longitudinal resistance in an endeavor to improve commutation by decreasing the short circuit current without increasing the contact drop. It will usually be found, however, if that even the increased cross resistance gives a voltage drop so low compared with the contact drop that no very pronounced effect is to be expected, although it is undoubtedly an improvement over the ordinary homogeneous material in this respect. Further steps in this direction will be mentioned later. In the average case the specific resistance is of negligible importance compared to the contact drop.

4—The contact drop is undoubtedly the most important single feature of the brush as it is directly responsible for the quality of commutation. If the contact drop is too low for for the thickness of brush and value of short circuit voltage across the brush, excessive short circuit currents will flow, the current will not be normally reversed in the short circuited coils, and poor commutation will result. On the other hand, if the contact drop is made unnecessarily high, the contact I_2R loss will be excessive with consequent high brush and commutator temperature.

In the actual average case, however, the value of contact drop is not particularly critical, the classes of brushes listed as medium or high contact drop fitting well the usual 115 or 230 Volt motor or generator, the "high" or even "very high" grades being picked for high speed 250 Volt generators and for 230 Volt field weakening motors.

There would be no objection to a contact drop of positive plus negative contacts of as high as 3 volts on a small 3:1 or 4:1 field weakening motor, but for constant speed apparatus it should never be necessary to exceed 1.5 to 2.0 volts for high speeds and less for low speeds. Low voltage, battery charging, plating, etc., of course come in another class, taking the lowest obtainable contact drop in carbon or graphite as well as metallic mixtures to reduce drop still further.

5—In picking a brush a low coefficient of friction should be sought for two reasons, first to obtain smooth action without chattering, and second, to reduce the energy loss and temperature rise, which may reach surprising values on large high speed commutators if low friction brushes are not used. The friction loss is of course reduced by lowering of spring pressure as well as by coefficient of friction, but it is seldom possible to reduce the pressure below about 1½ lbs. per sq. in. and the friction coefficient should be less than .2 on large commutators if friction loss is to be kept to a reasonable value.

Figures of .3 or more are acceptable on smaller commutators, particularly if box type holders are used whose action is not prejudiced by high friction.

B: Shape

1—Where the commutator speed is not very high and the highest grade of holder action is not required, rectangular brushes may be used to advantage, either clamped in a movable box or sliding in a rigid box.

While the clamped type is no longer used to any extent, it gives good operation on low speed machines and has the advantage of:

Definite position—no play in holder.

Long life—may be 3″ or 4″ long.
Low cost—no pigtails or special machine work.
The main disadvantage is the excessive inertia due to the box having to move with the brush.
The sliding box type allows the use of a rugged holder and a long wearing brush, and facilitates replacements in hard to get at locations.

2—For high speeds and where the best commutation is required, the beveled brush is indicated. The brush may be inclined only a small amount, as 10° or 15° from the perpendicular to commutator surface, in which case it must ordinarily be run trailing to get good action and avoid any tendency to chatter. This is not greatly different from the rectangular sliding box type except that the bevel tends to keep the brush in a definite position and prevent any play and change of brush seat which may occur in a radial holder.

For the very best operation it is doubtful if there is anything better than the reaction shape. Due to the bevel of the top of the brush the whole length of the brush is kept in contact with the holder so that no play can take place anywhere to affect the brush contact with the commutator. Due also to the relatively large inclination of about 30° from the perpendicular, brushes of moderate or low coefficient of friction operate practically as well with one rotation as the other. The brushes of course have less pressure against the holder and less friction and theoretically more freedom of movement when running leading, but practically it is hard to distinguish much difference in the action. If continuous operation in the trailing position is desired, the spring tension may be reduced to offset the wedging action which tends to increase the pressure.

C: Size

1—With a certain minimum total cross section of all the brushes of one polarity determined by the current rating of the machine and the permissible current density in the material, the thickest possible brush will require minimum total width and minimum commutator face.

On the average commutating pole machine the brush thickness is limited by the width of the commutating field, that is, the coils being commutated should be at all times within this field. For a lap wound armature this requires that $bd - Bd + t_1$ for full pitch armature coils or $bd - Bd + 2\,t_1$ for 1-slot short pitch armature coils, shall not appreciably exceed the width of the interpole shoe.

For an ordinary 4-pole wave-wound armature, the expression is a little more complex; viz:

$$bd + t_1 - \left(\frac{1}{2} \pm \frac{\text{No. of bars}}{\text{No. of poles}} \pm \text{coil pitch-coils [per slot)}\right) Bd$$

In each case B d — brush thickness x $\frac{\text{core dia.}}{\text{bar thickness}}$

$$Bd - \text{bar thickness} \times \frac{\text{core dia.}}{\text{comm. dia.}}$$

$$t_1 - \frac{\text{core periphery}}{\text{No. of slots}} - \text{slot pitch}$$

In many cases, such as 550 V. machines, or field weakening motors, where the total brush section required is relatively small, there is no necessity for using this maximum thickness, but on high current machines, where the tendency is to use thick brushes, the values stated should not be exceeded.

On non-interpole machines there is no definitely located commutating field and consequently no definite limit to brush thickness. In general, with brushes shifted to the best position for the average load, the commutating field is not of correct value for other loads, resulting in appreciable voltages across the face of the brush, more or less proportional to the brush width. In order to prevent excessive short circuit currents in the brush, with resultant sparking, the brush thickness must be kept to the minimum practicable value, the actual current density in the brush face being actually reduced by making the brush thinner up to a certain point. Due to the presence of greater short circuit currents, the nominal current density must be kept appreciably lower than on interpole machines. The old limit of 30 amps. per sq. in., which still frequently appears in specifications, was based upon non-interpole experience and is still not a bad figure to aim for. On non-interpole machines above the smaller sizes, while densities of 45 to 55 amps. per sq. in. are perfectly satisfactory on interpole apparatus. Non-interpole motors having short time ratings, or specially designed for minimum short circuit voltage, may however run far above 30 amps. per sq. in. without difficulty.

2—With the total cross section and the thickness determined, the total width naturally derives itself, the width of individual brushes being chosen if possible to give not less than two brushes per stud, to keep the weight or inertia of each brush within reasonable limits if for high speed operation, and to fit available brushholders. Brushes 2″ to 2½″ wide are satisfactory for low or moderate commutator speeds but for high speeds 1⅜″ to 1⅝″ is the usual limit in order that good contact with the commutator may be obtained without excessive spring pressure.

3—The length of the brush must be a compromise, endeavoring to give long life, light weight, and correct mechanical action.

A clamping type or a sliding box holder works well with a long brush so that with these holders the weight is the limiting factor up to the capacity of the holder.

With reaction holders, proper action requires that the brush should not be more than ¼″ to ⅜″ longer than the contact face of the holder, so that there is a pretty definite brush length for each size holder.

D: Special Construction

As mentioned above, efforts have been made from time to time to improve the commutating qualities of brushes by increasing the cross resistance.

The constructions described here have the same end in view, obtained by reducing the tendency toward high current density in the toe of the brush in several different ways.

1—An expedient that has occasionally been used is that of using very high resistance material for a small part of the brushes on each stud and advancing these brushes slightly with respect to the remainder. The main current is taken by the low resistance brushes, the final break coming on the high resistance toes.

2—A somewhat similar effect has been produced by milling V grooves in the faces of the brushes, giving a gradual decrease in contact surface as the toe is approached, and tending to give a low current value at final break.

3—By far the most effective means yet used is that originated by the Company with which the writer is connected, which consists essentially of dividing the brush into two parts, the toe portion being insulated from the rest of the brush. It will be seen that this introduces **three** contacts in the path of the current from the bar leaving the brush, with very effective results in obtaining good commutation in difficult cases.

A mechanical division of the brush into two parts, with a separate spring pressure for each part, is another construction which sometimes gives excellent results, not by reason of improvement in current distribution but because of betterment of mechanical conditions by decreased weight of each part and by the possibility of one part holding contact with the commutator when the other is thrown off.

In thus outlining the factors which enter into the selection of carbon brushes it appears that there are such a number of overlapping and more or less conflicting quantities involved that there can be no rough and ready means of determining exactly the proper size, shape, and grade of brush for each particular application but that judgment and experience and the good old method of trial and error are all likely to be called in before the final answer is reached. It is hoped, however, that a statement of the problem involved may aid in giving due consideration to each phase of the question and in coming to correct conclusions based on the necessities of each individual case.

Carbon Brushes for Motors and Generators

By G. M. LITTLE

CARBON brushes, which form a sliding contact with the commutator in a generator or motor, have an importance all out of proportion to their cost. A machine worth thousands of dollars will fail to operate and may even be destroyed if it is not equipped with brushes of a grade suited to its needs.

The conditions which must be taken care of by brushes in a motor or generator are very numerous and complex when compared with the requirements to be met by manufactured articles in many other lines of work.

No two machines on which the brushes are used have identically the same characteristics or operate under identical conditions, and these differences, which may be small and obscure, are often of sufficient importance to cause a brush which works well on one machine to fail utterly when transferred to the other machine having apparently the same operating characteristics, thus calling for a different grade of brush.

At present, the best a manufacturer can do is to make different grades of brushes, each of which will take care of a considerable number of these frequently hidden and variable conditions. However, if a grade of brush has been found which is satisfactory on a given machine, there is good reason to believe that the quality of this grade can be kept uniform.

A carbon brush is not a simple thing—one would conclude from the published data that there could be only a limited number of variables and that with a knowledge of these, definite recommendations could be made. Generally the properties mentioned are the hardness, the coefficient of friction, the contact drop, and the electrical resistance—and while these are of the utmost importance, there are many more properties, each of which throws a little light on the problem.

The ordinary process of manufacturing brushes is in outline as follows: A properly proportioned mixture of powdered coke, lamp-black, charcoal, and graphite, together with hot coal tar pitch, is prepared. This is heated, mixed thoroughly, allowed to cool, and ground to a flour. The flour is put in strong steel molds, heated, and pressed into plates under hydraulic pressure. The plates are packed in sand and baked for a week or so at about 1200°C. This completes the firing for many grades but others are given a second bake in a graphitizing furnace. In this furnace the temperature is so high that iron is volatilized and driven out, and coke is converted into graphite.

The manufacture of brushes bonded with synthetic resin (bakelite, durite, etc.) is an exception to the ordinary process of brush manufacture outlined above. The powdered coke, graphite, etc., are mixed with the correct amount of synthetic resin and solvent. This is stirred, heated, allowed to cool, powdered, pressed hot into plate form, and cured at a moderate temperature. The plates are not baked at 1200° as in ordinary practice and are never put through the graphitizing furnace.

The skill of the carbon manufacturer is shown

in the degree of control he has over the properties of the finished brushes. The apparent density (described below) may be lowered by using coarser flour, less pitch, lower molding pressure, lower molding temperatures, etc. The real density may be raised, for instance, by increasing the temperatures of the graphitizing furnace. The abrasiveness of the finished brush is almost entirely dependent on the presence of materials other than carbon and the amounts of these materials in the brush may be varied by the addition of certain natural graphites which contain a high percentage of iron, alumina, and silica.

The data given in this paper is the result of an extended research intended to devise improved methods of brush testing, to correlate some of the brush properties with the performance of brushes in different kinds of field service, and to improve the quality of the brushes manufactured for different services.

In this work there has been developed a schedule of brush observations and tests, of which a number are here described. They may be grouped under four general headings:

1. Preliminary Inspection.
2. Physical Properties.
3. Chemical Properties.
4. Operating Characteristics.

So far, all of the prominent makes of brushes, together with about 400 experimental samples, have been examined, at least in part, according to this schedule. From a study of these data, steps have already been taken by the brush engineers which have resulted in an improved and more uniform product.

PRELIMINARY INSPECTION

Observations are made as to the luster, feel, color, and finish. The sample is used as a crayon to mark on paper and the character of the mark is

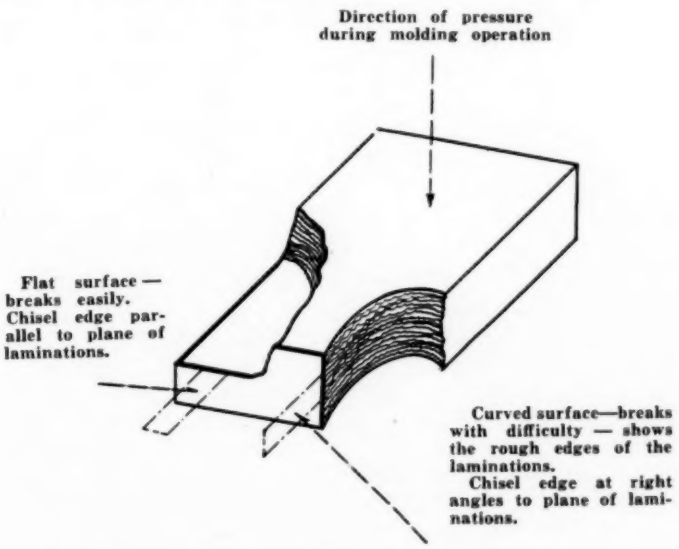
Direction of pressure during molding operation
Flat surface — breaks easily. Chisel edge parallel to plane of laminations.
Curved surface—breaks with difficulty — shows the rough edges of the laminations.
Chisel edge at right angles to plane of laminations.

FIG. 1—Showing Effects of Splitting a Laminated Brush.

noted. The polish a sample takes on rubbing, and the fineness of the grain are observed. The presence of a laminated structure is looked for. (Figs.1 and 2).

PHYSICAL PROPERTIES

The Heat Flow: This test was designed primarily to be a quick method of determining the thermal conductivity of brushes but, as the results

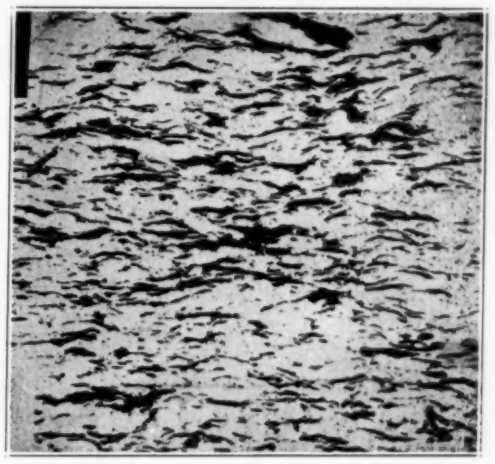

FIG. 2—Photo micrograph of a laminated metal-graphite brush. The white part is copper—the black is flake graphite. Taken in place at right angles to laminations.

do not depend solely upon the thermal conductivity, the term "Heat Flow" has been coined. The test shows how rapidly a brush, at room temperature, will conduct heat away from a small piece of hot copper which has been placed in firm contact with it. The results depend chiefly on the thermal conductivity of the brush and on the thermal conductivity of the contact film between the copper and the carbon.

The results check very well and show that a large range of values is to be expected. One surprising development is that several grades of brushes take heat away from the small piece of copper faster than will a large bar of pure copper, which probably shows that the thermal conductivity of the copper-carbon contact film is higher than that of the copper-copper contact film.

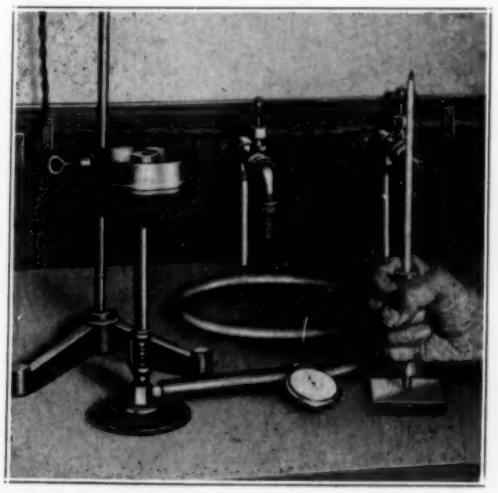

FIG. 3—Heat Flow Test.

The apparatus (Fig. 3) consists of a light, thin copper sheath which fits around the bulb of a

thermometer. A wooden handle provides means for pressing the end of this copper sheath firmly onto the brush to be tested. The sheath and thermometer are heated in a hot water bath. When the temperature reaches 96°C. the thermometer and sheath are removed from the bath and firmly pressed down on the brush, and the temperature is read at intervals of ten seconds. The curves (Fig. 4) show

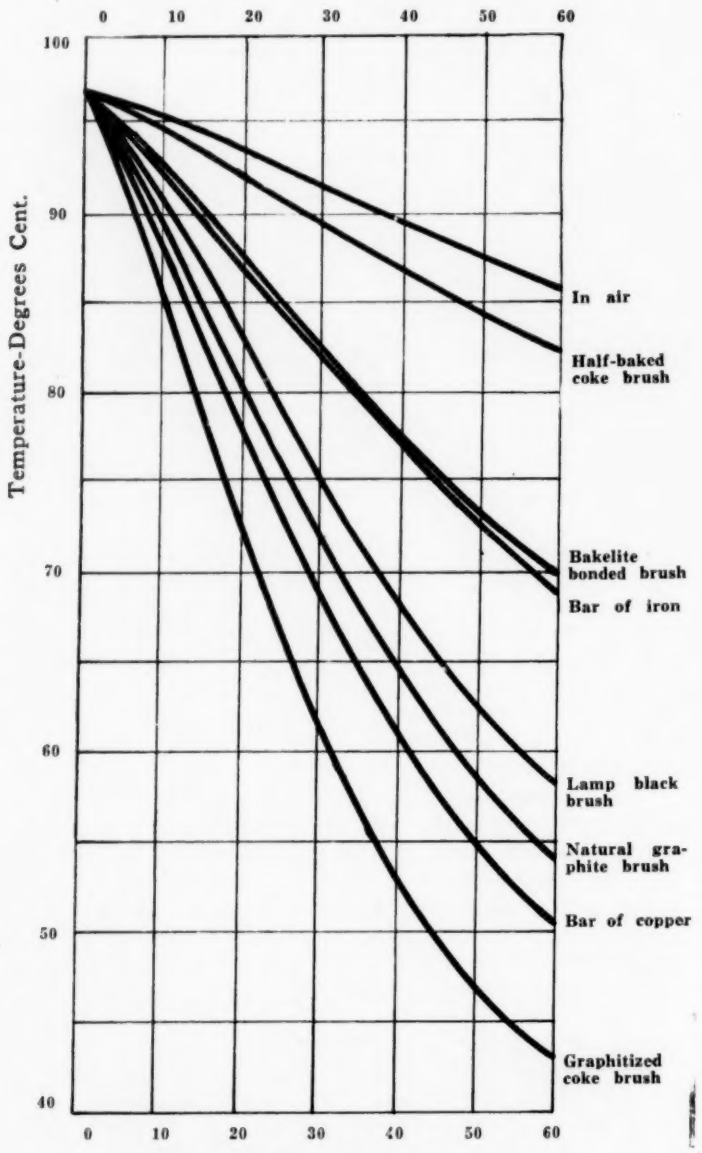

FIG. 4—Heat Flow Curves.

the wide range of results found between different brands of brushes. These results, on re-trial, check closely and in a general way the values vary with the electrical resistance of the brushes.

Air Flow Porosity: This test was designed primarily to be a quick method for determining the "porosity" of the brush. The test (Figs. 5 and 6) determines how many seconds it takes a constant volume of air under a uniform pressure or suction to pass through the pores of a specified area of the brush surface.

The test does not give any indication of the per cent of space occupied by the pores, but it does show whether the pores are connected together or whether they exist as more or less isolated cavities. One brush may contain five times as great a pore space as another, yet the air-flow test may show a much slower passage of air.

There is a wide range of results; some brushes

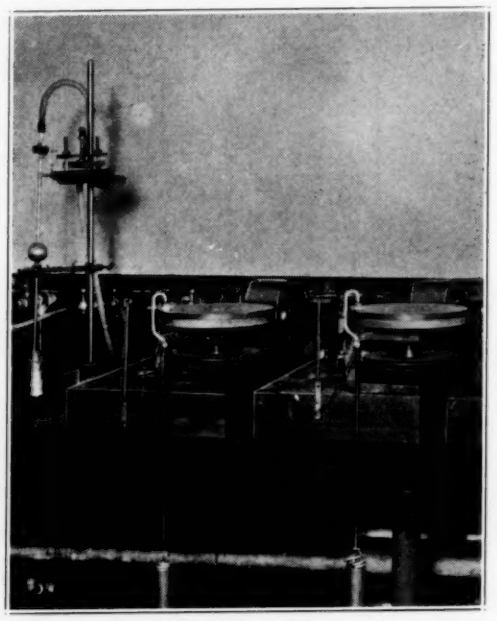

FIG. 5—Air Flow Porosity Apparatus and Machines for Determining Co-efficient of Friction and Contact Drop.

are almost like a sieve and the air will pass through in one second while other brushes may take as high as 500 seconds. The test, on repitition, checks well and does not injure the brush. This test is a good

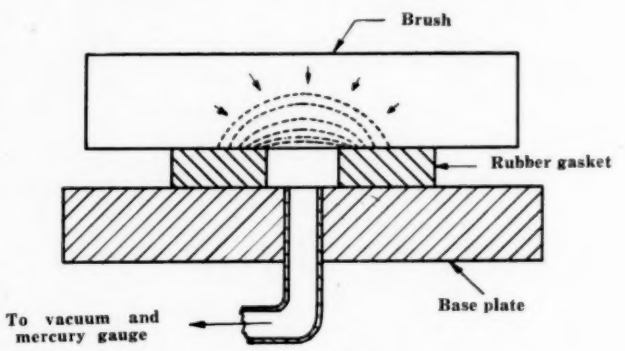

FIG. 6—Air Flow Porosity Test.

check as to brush uniformity and has other possibilities in that it may show the ability of a brush to free itself from the layer of air which is trapped between a brush and a commutator face, and which may prevent a good electrical contact with the commutator. (The presence of this trapped film of air is readily shown in the case of non-porous metal-graphite slip ring brushes, by drilling a hole down through the center of the brush and connecting it to a manometer gauge. Often a pressure of over 8″ of water is found, though sometimes a partial vacuum exists.)

Magnetic Susceptibility: Under this heading is recorded the action of a strong electromagnet on a brush that is free to move. (Figs. 7 and 8).

Many brushes contain a little iron uniformly

spread throughout the mass and, as this is probably the chief abrasive material in the brush, this indication of its presence or absence is of considerable interest. The iron probably exists in the brush as a hard cast iron or high-carbon steel. It can be polarized and will then act as a weak magnet. A

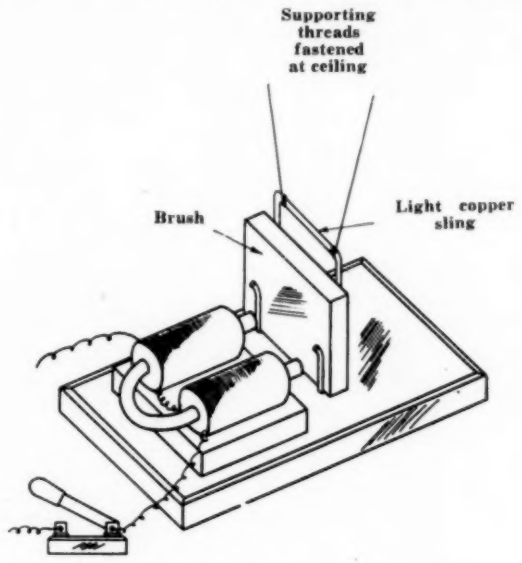

FIG. 7—The Magnetic Susceptibility Test.

brush that contains little or no iron, but does contain a high percentage of graphite, is repelled by the magnet. This is caused by the fact that graph-

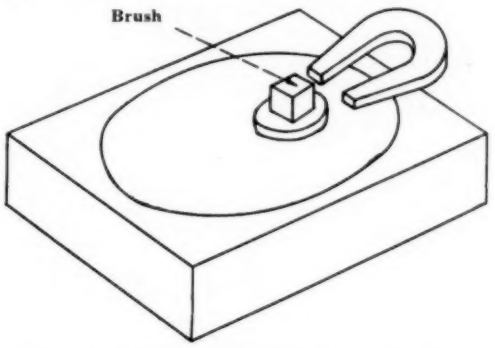

FIG. 8—Floating Cork Method of Showing the Magnetic and Diamagnetic Properties of a Brush.

ite is dia-magnetic—that is, it is repelled by either or both poles of a magnet. This can only be shown if the percent of iron is very low and means that the brush is non-abrasive and has probably been heated to a very high temperature in the graphitizing furnace.

Specific Resistance: This property of a brush is determined by the standard method used for other conducting solids and is of great value. It shows the current carrying capacity and furnishes some information as to the contact drop.

In certain grades of brushes, the resistance is not uniformly distributed. This is particularly true of some of the grades bonded with a synthetic resin. These have a laminated structure (Fig. 1) and the resistance measured in a direction parallel to the layers is apt to be only ¼ as high as the resistance measured in a direction perpendicular to the layers. There is considerable evidence supporting the belief that this irregular disposition of the resistance in a brush has a most desirable effect on commutation. The action is to cut down the destructive circulating current that flows from bar to bar under the brush surface.

The peculiar distribution of resistance in these brushes is not caused by any manual layering process, but occurs naturally in mixtures of this kind when they are subjected, in a plastic condition, to pressure in one direction. When, in the molding process, the plunger descends on the soft mass, the particles of which it is composed proceed to turn in such a way that their shortest dimension is in the direction of the pressure, and a distinctly laminated structure appears. A brush of this kind may be split much more readily in the direction of the layers than in the cross section.

Strength: The regular method in use at practically all carbon works for the measurement of strength is to determine the weight, applied at the middle, necessary to break a sample bar of uniform cross section, supported on V edges placed a standard distance apart. This test is sufficiently accurate, but it does not show the cumulative effect of re-

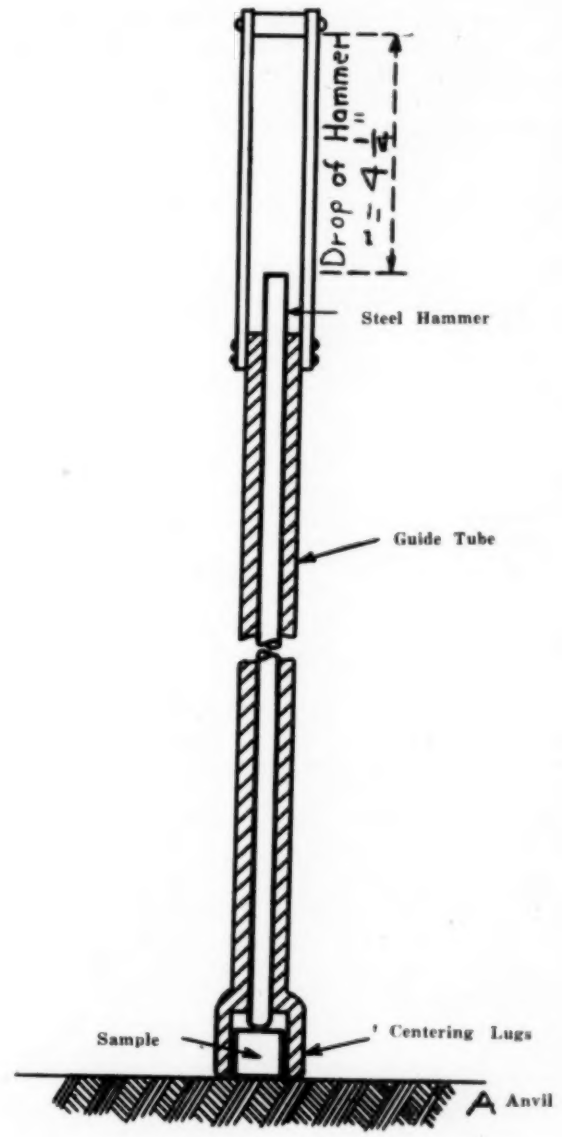

FIG. 9—Impact Tester.

peated strains or blows such as a brush is subjected to in traction service, nor is it applicable to small samples. It thus become necessary to devise some strength test that would overcome these defects. This situation arose as a result of serious breakage in severe service. To meet this condition, an impact testing apparatus was devised. This consists of a miniature pile driver (Fig. 9) in which a sliding weight strikes a sharp blow on a ⅜" cube cut from a brush. The number of blows required to break the sample is noted. With this apparatus, brushes which had broken in service and others that had been in the same service and had not broken were tested, and excellent agreement was found; the brushes that broke in service would break most readily in the impact tester.

As most of the field trouble occurred in cold weather, it was thought that perhaps heat, cold, and moisture were the cause. Tests were made to determine the effects of different conditions on the breaking-strength, and it was found that the same results were obtained even when the impact machine and the samples were operated in an enclosure that was kept below 0°C. It was shown that repeatedly raising the temperature of a brush to red heat weakened it somewhat. A brush sample was soaked in water then clamped between terminals, and a large current applied which caused a sudden elevation of temperature to bright red heat. This also weakened the brush slightly. Other things were tried, but an examination of new brushes that had just been taken from a shipping box and had never been in service showed variations in strength from brush to brush much greater than were the variations produced by temperature and moisture treatment.

Tone Test: It then becomes necessary to devise some way by which brushes direct from the shipper could be tested for strength and yet not be injured. An examination of the new brushes disclosed the fact that they differed from each other in the pitch of the sound that was given out, when the brushes, supported on a cloth pad, were struck on a corner with a wooden rod. High-pitch and low-pitch samples were selected from these new brushes. Samples were cut from them and given the impact test, and a direct relation was established between the pitch of the tone and the number of blows required to break the sample. Brushes that gave out a tone having a pitch below "G" on the musical scale were rejected and this stopped the breakage in service.

This test requires a musical ear and considerable trouble was experienced in obtaining men for the work. To an on-looker, this test has much in common with the xylophone of a regular orchestra and as a publicity stunt a carbon-brush xylophone has been built on which tunes may be played.

Apparent Density and the Real Density: The real and apparent densities have long been of value to the carbon-brush manufacturer. The apparent density tells him much concerning variations in his grinding and molding processes; the real density tells him much concerning his baking temperatures. These two determinations are of distinct value in the selection of brushes for special applications. The ordinary standard processes of determining the real and apparent densities of porous ceramic substances may be used, and give good results.

Porosity: There is a wide range in the percentage of pore space to be found in brushes of different grades. It runs all the way from 10%, in a very compact, fine-grained brush, to 45% in an open-grained, soft, coarse-textured variety. This is determined by dividing the difference between the real and the apparent density by the real density.

An effort was made to develop a rapid method for the determination of the percentage of pore space, and while it was not a success, it did bring to light a very interesting property of carbon brushes. Some grades **"adsorb"** air; that is, condense, possibly in a liquid form, a considerable amount of air on the surface of the carbon particles. This is readily shown by exhausting the air from a brush sample of known volume and measuring it. In some cases an amount of air of considerably greater volume than the sample itself will be obtained. (Fig. 10).

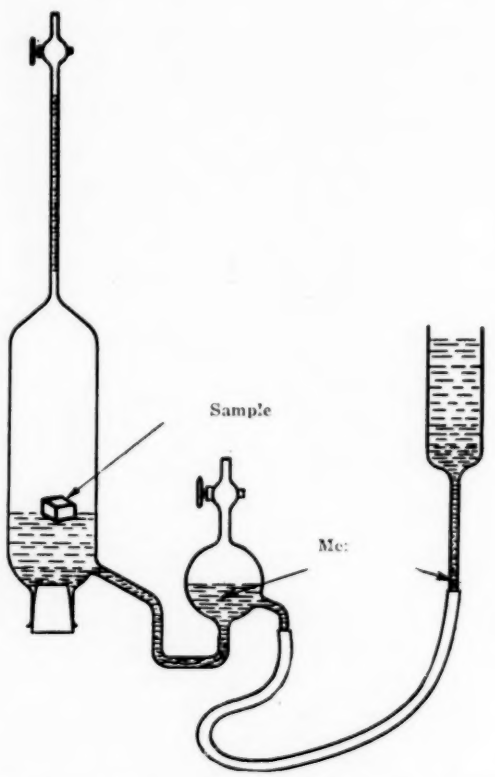

FIG. 10—Apparatus to Show Adsorbed Air.

CHEMICAL PROPERTIES

% Ash: All brushes contain certain amounts of materials other than carbon. These materials produce very pronounced effects on the performance of the brush, the most notable being a scouring or abrasive action on the surface of the commutator. The quantity and character of the abrasive material is determined by examination of the ash after ignition.

For the most part the ash is colored, varying in shade and tint from pure white to pink, yellowish red, brown and black. A white ash, as a rule, shows that a brush has been thoroughly graphitized. It has been heated so hot that the iron, which is the most frequent cause of pink, red or brown color, is volatilized and driven out. Such a brush is usually non-abrasive. A red or brown ash contains much

iron and, as a rule, indicates a brush which is quite abrasive.

It is to be observed that the ordinary forms of carbon — petroleum-coke, lamp-black, charcoal and graphite—that occur in brushes are not hard enough to cut copper and when an abrasive brush is needed one containing a certain percentage of iron is generally selected. A black ash usually indicates copper, although it may be unburned carbon that will disappear on further heating.

Efforts are being made to collect data showing the effect on brush performance of the presence in the ash of different amounts of various elements. This is a large field for investigation. It is found that the presence of so little as a tenth of one per cent of certain impurities will make a profound difference in the behavior of a brush. It may be noted here that the abrasive action of these foreign materials is peculiar.

It is necessary that some current shall flow in order to bring into play the abrasive cutting action. An "abrasive" brush may be run without current on a commutator for months with scarcely any wearing action, but immediately upon turning on the current the cutting of the surface of the commutator commences. It would appear that there is something more than straight mechanical abrasion here; possibly an electrolytic action.

Some materials seem to cause a change in the character of the minute arcs which frequently exist between the brush face and the rapidly moving commutator. The presence of measurable amounts of ash in a brush may also be shown by an x-ray examination. Carbon is transparent to the x-rays while the materials that go to make up the ash are for the most part opaque, so that a brush containing a high percentage of ash throws a noticeably dark shadow.

Volatile Matter: This test is used more in the preliminary examinations of the materials from which the brushes are made, but some information may be obtained by its use in the examination of certain grades of finished brushes. Thus the presence of notable amounts of volatile matter in a synthetic resin bonded brush shows that it has not been cured sufficiently. A volatile-matter test of "doped" (paraffined) brushes gives an indication as to how much of the dope is present. This test is conducted just as volatile matter in coal is determined. A weighed sample is heated to bright redness in a covered crucible. The loss in weight is the volatile matter.

OPERATING CHARACTERISTICS

Contact Drop: The contact drop is a measure of the number of volts required to force a known current across the contact between a brush and the surface of the commutator. It is the chief distinguishing feature which enables carbon brushes to commutate well, where metal brushes fail. The contact drop of carbon brushes is several times as great as that of copper brushes and is useful in preventing a large current-flow and hence a large spark, when the adjacent bars of a commutator are connected by the brush.

Contact drop is determined on a special apparatus (Fig. 5) which consists of a horizontally rotating copper disc or wheel. The brush sample is forced down on its surface by means of a weight. A constant direct current is sent from the plate to the brush. After a preliminary run of 24 hours, readings are taken for several days on a voltmeter whose terminals make contact with the plate and the brush and the contact drop obtained by averaging these results.

Coefficient of Friction: It is the writer's opinion that the coefficient of friction determination is misleading. The general belief exists that if the coefficient of friction is high there must necessarily be a decided wearing and abrasion of the surface of the commutator. The evidence, as shown by tests on the machine here described, is decidedly to the contrary.

The coefficient of friction is determined at the same time as the contact drop, by means of an adjustable sliding weight on a rocker arm. The rocker arm is attached to the brush holder in such manner that it measures the horizontal drag or pull of the brush. The horizontal pull, divided by the vertical pressure is the coefficient of friction. These two tests, the contact drop and the coefficient of friction, are accurate and reproducible under the conditions in the laboratory, but it is likely that under the very different conditions found in practice, radically different results are obtained. A great many samples have been tested on this machine and only a fair agreement is found to exist between the results and the actual behavior of the brushes in service. Contrary to what one would expect, a very abrasive brush that will score and scrape the surface of the plate may have a much lower coefficient of friction and a lower contact drop than another non-abrasive brush which gives a very high polish, but which seems to adhere to the surface of the plate. This may be the same effect as the well-known sticking together of two metal plates whose surfaces are very flat and true.

Life and Commutation: In addition to the above-mentioned analytical tests, the laboratories are equipped with a number of commercial motors and generators of different kinds, and samples of the brushes are given service runs in these machines which are, for the most part, operated at standard speed and load. However, some of the tests call for over-load condition, some require the commutators to be flooded with oil, and some require intermittent starting and stopping, etc.

The brushes may fail in a number of different ways. For example, they may be short lived, they may break, chip, expand and stick in the holders, disintegrate and form dust, or show excessive side wear, or they may act on the surface of the commutator in such manner as to cause high mica, burnt bars, smutty surface, ring fire, packed slots, flats, grooves, high temperatures, noise, sparking, etc.

The condition of the machine means a great deal in a test of this kind. The bearings may be worn, the commutator out of true, the commutator oily, the armature unbalanced, or the mica poorly undercut; or the machine may operate where there is dust or fumes, the spring-pressure may be too high or too low, etc. The foregoing and other conditions have to be watched and avoided. A brush failure does not mean much unless the conditions are known.

When a brush is commutating well there may

be no sparking, or if there is any sparking at all it will occur uniformly around the commutator. It is interesting to watch, with the "rotoscope" (made by the Elliott Bros., London), a rotating commutator on which a group of bars has become burned. The sparking is seen to occur only when the burned bars are under the brushes; the rest of the commutator may be operating perfectly and show no sparks.

In addition to the apparatus for determining the contact drop and the coefficient of friction, special machines have been developed such as (1) an apparatus for developing a better understanding of the action of the circulating current that flows from bar to brush to bar under the brush face, (2) a machine for studying the behavior of different grades of carbon brushes when subjected to extremely short arcs, (3) a special traction-brush testing machine which shows differences in commutation and life, (4) a machine which determines the tendency of a brush to "chip," (5) a machine for measuring the ability of a brush to resist "side wear," and (6) a slip-ring test device.

Work with the apparatus herein mentioned gives results which constantly throw more light on the very obscure and complicated problems connected with brushes. The whole development is moving forward. Much interesting and instructive information has already been obtained, and much is yet to be expected.

Discussion

J. Ulvad: Being present at the dinner given in Pittsburgh, November 17, 1928, by the Association of Iron & Steel Electrical Engineers, where the subject of factors in design of motors governing the proper selection of carbon brushes was discussed, I learned that the Committee on standardization of carbon brushes would like to hear from manufacturers who have endeavored to standardize their brushes. Mr. A. M. McCutcheon spoke very clearly on the subject and strongly brought forth that there were no other ways of selecting brushes than trying them in actual service and we have come to the same conclusion.

I fully appreciate the research work done by Mr. G. N. Little in the brush field but feel that this work will be of greater importance to the brush manufacturers than to the motor engineers.

We have tried to select brushes according to their characteristics but did not succeed and we are now selecting brushes only after actual tests in service. However, selecting brushes in this manner is not an easy matter. There are quite a number of factors bearing upon the result such as:

1. The amount of service to which the unit is subjected.
2. The maintenance of the commutator.
3. The condition under which the unit is to operate.
4. The ability of the commutator to stay round.
5. The atmospheric conditions to which the unit is exposed.

If only one unit was to be tested the matter would be rather simple; however, where a number of units are to operate under different conditions, as outlined above, the matter becomes quite complicated.

I am giving below a brief description of how we standardize our brushes. We started to standardize our brushes in 1923 and the problems with which we were confronted were as follows:

We are manufacturing DC units varying in Horse Power from 2 to 350, these units being used for the following:

Geared Elevator Motors. Furnace Hoist Motors.
Gearless Elevator Motors. Escalator Motors.
Motor Generator Sets. Pump Motors.

The voltage range being from 60 to 600 volts, the higher limit of which we have rarely exceeded.

For these units we originally used 10 different grades of brushes and approximately 25 different sizes, a total of approximately 250 brushes. The brushes were all of the rectangular type, having a bottom angle of 9-10 degrees. The shunts had quite different lengths and were either of the cemented or screw type. The commutators are assembled with amber Micanite and are all undercut with the exception of the slow speed gearless traction motor, and commutators having very small diameters.

First of all, it was necessary to develop a new brush-holder and another shape for the brush, as the rectangular brush was unsatisfactory for the following reasons: As the motors are operated in both directions the clearance in the brush-holder would allow the brush to shift from side to side thereby destroying the brush seat and wearing off the edges of the brushes, consequently reducing the brush area in contact with the commutator surface. This, in turn, would cause improper commutation, noisy operation and chattering of the brushes in the holders.

A brush similar to the one used in the Bayliss holder was adopted and to obtain equal performance of the brush when operating in both directions, the following angles were adopted standard:

Top angle = 40°.
Bottom angle = 30°.

The holder was made up in two parts, a box and a base. This was done so that the same base could be used with different box sizes, thereby reducing the number of parts to be kept on hand. It was decided to standardize on a 5" long shunt connection, this connection to be cemented in the brush.

It was now necessary to cut down the number of brush sizes and tests were started to determine what sizes would be most useful. For example, a motor which ordinarily used a 7/16" thick brush was tried with a ½" and a ⅜" thick brush. After extensive testing the following sizes were adopted as standard:

2"x¼"x⅞".
2"x⅜"x1".
2"x½"x1½".
2"x⅝"x1½".
2"x⅞"x1½".

This gives five different sizes instead of twenty-five, and we have so far found that these brush sizes are sufficient for our needs.

We then called on different brush manufacturers and asked them to give us their recommendations as to what brushes they would use for our different equipment. However, we strongly pointed out that they should confine themselves to as few grades as possible and also that the performance of the brush was to be considered and not the price. In this manner, we obtained approximately 15 different grades of brushes for testing.

Comparison between the characteristics of these brushes as supplied by the manufacturers showed a great variation, for example, the variation in the contact drop was 1:4 and the coefficient of friction varied by the same amount. From this it will be seen that apparently the manufacturers themselves disagreed about selecting brushes according to their characteristics, or in other words, selecting brushes from laboratory tests.

The test brushes were then installed on new equipment and distributed all over the United States, which in our company, is divided up into Zones. Each Zone was then furnished with a questionnaire of which a sample is attached and they were to return this questionnaire after the brushes had been in service for some time.

Several hundred motors and generators were, in this manner, kept under observation, but the result obtained was not at all satisfactory. In some Zones a certain grade of brush was highly favored, whereas in other Zones the same brush was reported to work very unsatisfactorily. It must, of course, here be taken into consideration that all commutators did not receive the same attention, nor was the equipment subjected to the same service, the result being that the questionnaire did not fulfill the purpose since it was left to the construction men in the Zone to pass judgment on the brushes. In summarizing the results obtained from the questionnaire it was impossible to draw any definite conclusion as to what brushes should be adopted standard.

It was therefore decided to confine the testing of the brushes to a place where one engineer could keep in constant touch with the performance of the brushes and then have this engineer select the brushes. A number of test brushes were then installed in New York City, and after a test period of approximately 18 months a selection was made of four different grades which showed the best performance. These four grade were then adopted temporarily as standard and kept under close observation and in the course of another year these grades were reduced to three grades, of which one is a substitute for another, so in reality we have now only two grades of brushes and five different sizes; in other words, ten different brushes altogether.

These brushes will, however, not do for service work except when we also supply new brush holders, but this is done wherever possible and the old style brush will thus gradually die out.

The brush sizes selected are all in accordance with "Simplified Practice Recommendation No. 56 for Brushes." The shunt connections, however, do not quite agree with this recommendation but could easily be brought in line with it.

A. J. Standing: First of all I want to congratulate the Pittsburgh Section on this meeting, the number present, the speakers, and the manner in which it has been handled. The subject is of particular interest to those who are operating in the steel industry because the demand of the times is to everlastingly keep after costs and one of our items of cost is the brush bill, therefore we should endeavor to bring it down to a tangible basis. I realize a motor designer should not be expected to design a motor to meet a certain brush. That would be a case of "the tail wagging the dog," but if the motor designer by means of certain variables can conform to more or less standard brushes it would be a saving to those of us who use brushes. Because of the variation of brushes, we cannot buy in quantity. There would be numerous opportunities for a corporation to arrange brush purchases to get the best possible price were the brushes more nearly standard. Our plant happens to be largely standardized as regards variety of motors and we have about 25 different styles and sizes of brushes which are continually purchased. Besides these 25, we have two or three bins full of brushes which I asked the storekeeper why he did not get rid of. He said there are motors that occasionally need those brushes so to take care of these odd motors we have to keep on carrying these brushes until we can eliminate the motors. An interesting study might be made of the lubrication of armatures in the plant as the troubles are partly from oil causing poor commutation. The repairman of a plant when he makes changes on armature tries to get going as quickly as possible without always giving the brushes a fair show. There are a lot of troubles not fairly chargeable to brushes. Of 1,700 motors at our plant, there are about 5 per cent of these armatures in the shop per month. That figure is not entirely fair for this reason. The armature repair records cover all work including fractional horsepower armatures not counted in the 1,700 total. The actual figure should be somewhat less than 5 per cent. There is no question but what our various plants have made notable strides in reducing the number of sizes of brushes carried in stock. We strive to get a grade lower in price than some of the grades we now feel it is necessary to use.

Mr. MacCutcheon referred to five major items and he also referred to the "minor item" of shunts and their adjustments. We find that is a major item which gives concern to all of us who continually strive to have shunts properly attached and have men use them when they are attached. Mr. MacCutcheon also discussed the reason why spring tension varies over the life of the brush. We have found in case of some of the most expensive brushes that it pays us to put in fiber filler blocks in order to get the maximum life out of a brush while depending on the spring to keep the proper tension. This filler on top of the brush brings the spring back to its normal working range as the brush wears down.

In order to obviate the condition of undercut commutators which was mentioned, our commutators are undercut and the slot clearance filled with some pasty compound which keeps the slot clean and will not interfere with commutation.

Having gone through the Westinghouse Research

Laboratory this Spring and seeing the work done, I was interested in seeing and hearing Mr. Little's demonstration, but I think that it is beyond the scope of the average motor inspector to be so attuned as to make proper selection by sound of the brushes.

E. A. Lapham: When I came here this evening, I thought it might be necessary to defend the brush manufacturers. I was not aware that the motor manufacturers and operators appreciated our problems as well as they do as is indicated by papers read here tonight.

The standardization of brush sizes in England was mentioned and I can perhaps throw a little further light on this. This was brought about by the use of small brushes, it being found that certain sizes of small brushes which were used on a wide range of industrial motors could be also used on larger units, such as rotary converters and generators, by increasing the number of brushes over what had been their practice in the past. This increased the brush gear cost but this was largely offset by the advantage of standardization which enabled larger quantity buying.

Another item of interest to me was a remark that brush salesmen should do less guessing with brush application. I think that most of the reputable brush manufacturers realize the importance of analyzing carefully machine conditions before making brush recommendations. Remember, in the event of brush failure, we suffer as much as anyone—usually more.

When we develop a new grade of brush, we test it thoroughly in our own laboratory and then offer it in the field to such customers as are willing to experiment with it. We have always found plenty of co-operation and it is only after testing for many months in this manner that brushes are offered by us to the general trade. We do not think any brush manufacturer offers a brush unless he feels confident it will take care of the job.

E. A. Williford: I think the information given by the previous speakers is one of the most comprehensive I have ever listened to on this subject. I did not know the motor manufacturer had taken so seriously the standardization of brush sizes. Reference was made to a committee doing some of this work. The Department of Commerce under Herbert Hoover, in looking about for something to simplify, discovered the carbon brush problem, appointed a committee and passed on to me the chairmanship of that committee. I had something to say about the membership of it, and knowing the brush problem in the steel mills from two years' experience in brush peddling, I felt the iron and steel engineers should be represented on that committee and they are represented by Mr. Cummins. We have done some work in the way of simplification. We have not made the progress we would like to have made, but I believe the idea is permeating through industry through the influence of such fellows as Mr. Petty. There is a general desire to get some sort of reduction in the number of sizes. So far as brushholder types are concerned, as mentioned by Mr. MacCutcheon, there is bound to be engineering difference of opinion that will always have to be taken into consideration. However, I would like to offer this suggestion: You can get the reaction type effect with a box type holder by merely changing the bevel angle of the brush. The question of grades is not so simple. Our company has one grade which takes care of approximately 30 per cent of our business, another 25 per cent, and another 22, making a total of about 80 per cent on three grades and we have about 40 grades; and every other carbon brush manufacturer is in a similar position. May I ask that when we want you to change to some brush grade we believe to be better than what you are now using of our own make, you do not object too strongly because you have had success with the older grade, because we may give you something much better, and it is in the interest of simplification which finds its way into your costs.

Some time ago, the Pittsburgh Coal Company asked us to make a survey of their electrical equipment. We found that they had approximately one thousand styles of brushes and by merely changing the angle of bevel, changing the style of shunts and changing the grade, we were able to reduce that to 100 styles. You can imagine what that has done to their stores problem.

So far as widths are concerned, all the larger manufacturers are tending toward narrow widths as being most desirable. Another committee, the Carbon Section of the National Electrical Manufacturers Association, has discussed some of these problems and at our last meeting invited the Motor and Generator Section of N. E. M. A. to meet with us to see what can be done to reduce the number of sizes of brushes. During the war our Navy found that the German fleet had standardized on brushes; there was one grade and one size on all naval equipment. That was accomplished by using small brushes and where they needed increased carrying capacity, they did that by increasing the number of brushes. But that may not be ideal for general industrial practice.

On lengths our section is inclined to feel that a great deal of sacrifice could be made there in the interest of uniformity. We are inclined to believe three lengths will serve efficiently, for example, 1", 1½" and 2", maybe 1½", 2" and 2½". But the lengths play such a small part in the actual operation of the brush, we feel a number of concessions might be made there.

The question of low inertia was brought up by Mr. Lang. The use of small brushes tends to reduce the inertia and makes for better commutation. The larger the brush the harder it is to keep on the slip ring or commutator. Anything done to make brushes smaller, the Carbon Manufacturers believe is in the interest of longer brush life.

I would like to see a little more active co-operation, if possible, by the Association of Iron & Steel Electrical Engineers with our Department of Commerce Committee on Simplification. I believe you are in sympathy with the movement. I know Mr. Cummins is interested. I do not know how he is fixed for appropriation of funds to pay his expenses to attend our meetings but we desire your co-operation in this work. We'll hold our meetings in Pittsburgh if thereby we can have your help. You are one of the largest consumers of carbon brushes in

the country. You have a vital interest at stake and we hope your interest will take more active form in the actual participation of your Association.

A. C. Cummins: Progress in educating the public in the necessity for standardization has been rapidly accelerated during the past few years and I doubt if any thinking person will offer serious objections to any general program for standardization, unless it seriously interferes with freedom in conducting the business in which a person is personally interested. Even in such cases, the majority now realize that what is good for an industry as a whole is also good for the individual in such an industry. The standardization of brushes should accomplish as much for industry as many of the other standardization activities, and I am therefore fully in accord with the speakers of the evening in urging that this program be actively pushed.

There is one feature in selecting brush standards which must be given careful consideration, viz., that very great care must be exercised to see that no compromise in sizes or quality that will be detrimental to the maintenance of electrical machinery are made. The reason for making this statement is that the cost of carbon brushes to the user is not a major item in the total cost of keeping motors in service. If Mr. Standing's figures are expressed in a slightly different way, you will find $3.00 per motor year is spent for brush purchases. Mr. Standing's plant has quite a number of motors which are not of the most modern type, and it is therefore to be expected that the money spent for brushes will be somewhat greater than that spent in plants entirely equipped with motors of the most modern design. Brushes purchased per year in plants operating modern motors exclusively are about $2.00 to $2.50 per motor year, but may be as high as $4.00 per motor year in plants entirely equipped with motors of obsolete design, if figures collected last spring are reliable. In any event, it is estimated the purchase price of the brushes should not exceed 12 per cent of the total cost of motor maintenance. Furthermore, by careful storekeeping methods, it is possible to attain a turnover of 300 per cent per year in the motor brush inventory account, so that the saving to be expected by reduced inventory is not large.

Therefore standardization of motor brushes if accomplished at the expense of higher maintenance of other features may easily wipe out all the financial savings accomplished in reduced prices and lower inventory. I think it will be generally agreed by the steel mill maintenance engineers that the adoption of better motor bearings, whether of the anti-friction or sleeve type have not altered the fact that usually the commutator is still the first thing to cause motor replacements. In the days of inadequate bearing designs, commutators failed usually on account of ground or short circuits. When oil on the commutator is eliminated it is still found that commutators fail first, but not for the same reasons. Commutators are repaired in modern motors with improved bearings because they have worn down until under cutting is no longer affected, and high mica results in flat commutators or else excessive wear grooves them to such an extent that re-turning is necessary.

The ideal condition to secure maximum motor life per dollar of maintenance cost would be to have all parts of the motor require attention at the same time. It would then be possible to replace bearings, coils, and commutators, at the cost of one motor change.

In conclusion let me say that I believe we should back the brush standardization project, but that we should not let enthusiasm for reducing the number of grades and sizes result in limiting the designers in giving motors having longer commutator life.

A. B. Holcomb: The question of Brush Holders has been brought in and my experience was along the line of brushes before I got into the Brush Holder end of it. I was very much interested in Mr. MacCutcheon's remarks when he said he would confine himself to three or four different types and sizes of Brush Holders. We have been building Brush Holders for electrical machines for about 20 years and up until about 1920 all holders we built were for railway type motors. Since then, we have developed an industrial line for both modern and older types of machines. We have some 2,200 different patterns for Brush Holders for machines in active service today and fully half of those are for machines in industrial service—not railway service. That does not mean we have built a brush holder pattern for every application. Our standard practice wherever possible is to use a modern type of brush holder for machines equipped a number of years ago and one pattern can in many cases be used for holders for several different machines. So you can see the multiplicity of types in brush holders and I think Mr. MacCutcheon was very optimistic when he spoke of three or four different types.

With regard to grades and brush sizes, we have quite a number of cases where customers are interested in reducing the number of sizes and when they find it necessary to renew brush holders, will, as far as possible, choose a size of brush which they are carrying in stock for another machine.

The choice of grades and sizes from the motor manufacturers' point of view is different from choosing brush sizes and grades from the operating man's point of view and I would like to hear from the operating men as to what percentage of their machines are using the same grade of brush that was originally used in the machine. This is another factor which increases the grades in service. Judging from the various remarks I have heard this evening, the question has been in almost all cases as to what brush shall be chosen to operate satisfactorily by the manufacturer.

I want to ask the question of motor manufacturers, what changes could possibly be made in the design of the motor to increase the latitude of choice of a brush to operate on that motor after it is built? As I have heard the statements tonight, nearly everything has been said in the choosing of a brush after the machine is built.

Another point which has a bearing on the number of grades of brushes is that after a brush is in service for a number of years, you will find a condition like this: The operating man says, I have a brush that never did work right; have you a brush that will work right. That is the reason for a

number of the grades tried on machines in service. I want to say right here the brush is experimented with frequently to find out why the machine is not commutating satisfactorily. There are a number of cases where after trying a number of different kinds of brushes they come to the conclusion that something must be wrong with the machine, possibly commutator trouble, possibly trouble in Brush Holders, possibly where equalizer connecting rings had become unfastened. When a machine begins to commutate unsatisfactorily, the chances are that changing the grade of brush will not correct the trouble and it is a good plan to study the machine itself to find what is the trouble.

In connection with the thickness of the brush, I want to ask Mr. MacCutcheon in particular about the question he raised on restricting brush thicknesses to multiples of ⅛". He made the statement that they have found 7/16" to give more satisfactory results in certain cases then either ½" or ⅜" which I have no doubt is true. Now machines can be operated with brushes at various angles and there is a certain amount of variation which is allowable. If brush sizes were standardized so that ½" and ⅜" were standard thicknesses, could he not use ⅜" with a certain bevel to accomplish 7/16" contact with the commutator and would this give satisfactory results.

So far as widths are concerned, the standardization I spoke of which has occurred in some plants by trying to use sizes in stock has not been difficult because of brush widths. When we get into larger machines with a number of brush holders per stud, it is always possible to increase or decrease the number of Brush Holders and so utilize a brush of standard width.

I agree with Mr. MacCutcheon that you could not keep down to less than three lengths of brushes. I think, however, that three could be used satisfactorily. We have designed all our holders to completely wear out the brush but a holder which does not do this obviously has a tendency to increase the number of brush lengths.

Another factor which is partly responsible for the wide number of grades that are offered to both motor manufacturers and operating men is that price has a bearing on the choice of brush as well as how it will operate on a machine. I was interested in Mr. Williamson's remark that the carbon brush has an importance all out of proportion to its cost. If the cost did not enter into it, the number of grades could be reduced quite materially. A number of large plants have gone into the question of brush tests pretty thoroughly. Two or three made thorough tests on certain types of machines and have come to quite definite conclusions as a result of those tests and those tests include operation, brush life, brush type, and cost. That information which has been obtained by a number of companies should be furnished the standardization committee so that they can have the result of those tests in their findings.

When the question of standardizing the mill motor was brought up, we thought it could not be done, but, today it is done and I see no reason if operating men want it badly enough why a certain extent of standardization of brush sizes and grades cannot be accomplished as well as with the mill motors.

J. A. Hammond: During the first nine months of 1927 our records show that we furnished 10,000 sizes and grades of brushes. That includes only the different sizes and grades. If you take into consideration the different bevels, shunt types and special work, that will go as high as 300,000 types of brushes. That I think is quite significant to the standardization program, and I believe Mr. Standing's figure of 51 cents could probably be cut in half if we can get them reduced to what we consider the essential sizes and grades.

M. S. May: So much has been said about brush standardization, and by men so experienced in brush applications, that I hesitate to attempt to add anything.

However, I would like to further emphasize the points brought out regarding lifting clips and hammer plates, which I feel are very important. It seems to me that we have more trouble and are forced to more hand operations on such devices than on anything else in connection with brush manufacture. Many lifting clips and hammer plates are entirely "special" and this naturally runs the cost of brushes up very decidedly. I feel, therefore, that standardization of clips, plates and such brush fittings is even more important than that of brush dimensions, which are more readily controlled and varied by the brush manufacturer.

In the discussion of brush thickness, mention was not made of the variation in voltage between adjacent commutator bars. Different manufacturers use different limits for this voltage and this naturally has an effect on the brush requirements. However, I believe that the first speaker's remarks on reactance voltage cover this phase of the subject.

E. C. Gerber: At the Warren Plant, Republic Iron & Steel Co., they have reduced the number of brush sizes from 288 down to 138. Most of those changes were attained in cases where we had smaller angles on the face of the brush. In all cases where other physical dimensions of the brushes were the same the brushes were made square ends, which accounted for changes in size. They also found in mill motors, say for 1⅝", 1¾", 1 7/16", 1 9/16" and 1 15/16" we could assign an arbitrary length and we arbitrarily assigned a length of 1¾", and these lengths were found in most cases to be satisfactory.

As to number of grade they have found it possible on a number of generators to assign one grade in 90 per cent of the cases. On mill motors, one grade. On shunt and compound wound two grades were required.

A. Milne Ramsey: There is very little left to say in the way of standardization on brushes. However, we have very carefully gone into the question and find in the Pittsburgh District, especially, there are probably 35 styles of brushes, and in all these styles any dimension combination can be given, so that the total number is almost without limit. Grades can be limited to a very much smaller number if some of the users will condescend to take the recommendations of the carbon manufacturers and

use brushes which they have more recently developed and which are a decided improvement over those of a few years ago.

Mr. Cramer brought out the point as to the position of pigtails and lengths of shunts. There seems to be absolutely no standard in this respect, sometimes they are on the right hand side and sometimes on the left hand side of the brush, also the length of the shunt could be kept within certain standards such as 3½", 5½" and 7½". We have not taken these items into consideration in the 35 different styles just mentioned. So you will see anything that can be done to standardize on particular styles and hold those styles to certain sizes, as close as possible, will help not only the consumer but the brush manufacturer by reducing the number of styles and sizes carried in stock.

J. H. Albrecht: The standardization of Carbon Brushes presents a number of difficulties most of which have been touched upon tonight. If the Operators can find any common ground, I am sure that all the Carbon Brush Companies will be glad to co-operate.

As regards the application of Carbon Brushes, the motor problem is comparatively simple. Practically the entire range of motor applications can be covered with a very few grades of material. The Direct Current Generator however, is much more complicated and these are the applications over which the Carbon Engineer loses sleep. While Mr. MacCutcheon confined his remarks to the motor field I believe he had absolutely the right idea when he stated that many brush problems would be eliminated if the manufacturer followed his machines more carefully after they had been placed in service. The fact that a carbon brush successfully passes the manufacturers test does not always mean that it is always the right brush for that application. As regards brush performance, the standard commercial tests are usually far from conclusive. Bear in mind that the test floor run is very short as the machine is never run longer than the time necessary for the temperatures to become constant. In various sizes of machines, this run may last from four to sixteen hours. At the start of the test, the commutator is in perfect condition, the brushes are usually carefully seated, the operating conditions as regards dirt, gas, load, etc., are ideal. Absolutely no indication of the abrasive or cutting action of the brush can be obtained in so short a run. A machine might pass this test with flying colors. However, if it is placed in service in the dirty substation or around the Coke Oven, or Blast Furnace Plant where it is exposed to gas fumes, a new condition immediately arises. If the machine is shut down say over a Sunday, the gas attacks the commutator copper and rapidly builds up a high resistance film. When the machine starts up Monday morning, this film causes sparking under the brushes with a further oxidization of the commutator and general unsatisfactory operation of the machine. The brush which may have proven satisfactory on the manufacturer's test floor must now be replaced with a brush having much more cleaning action to get rid of the high resistance film and to scour from the commutator the affect of both the gas and the resultant sparking. Under these conditions, commutator wear soon becomes evident. While the Operating man may complain, it is the condition which cannot be avoided.

However, under normal operating conditions, it should not be necessary to use abrasize brushes. In spite of this fact a number of large machines every year leave the manufacturer's shipping floor equipped with brushes which everybody in the Industry knows to be highly abrasive. When a machine on the test floor does not commutate satisfactory, the Designing Engineer will first make changes in his machine adjustments and if this does not improve the commutation, he will invariably be forced to use an abrasive brush to remove the effects of poor commutation. The Operating man should consider that when he receives such a machine that the machine is not right and he should not accept it. Commutators will very quickly begin to wear and the Carbon Brush Engineer receives a kick on the performance of his material. While it is probably not good commercial policy to offend manufacturers who are large purchasers of carbon brushes, the carbon brush company should not hesitate to state that the material is abrasive in its nature and that commutator wear must be expected. The Carbon Brush Companies each year spend quite a considerable amount of money in furnishing test sets of brushes to attempt to correct the commutation of machines which have some inherent defect either in design or adjustment. This increases the overhead and ultimately comes back to the consumer. Of course, this does not apply to the legitimate operating tests of new grades which must be made and which should be regarded as a necessary development charge.

A. W. Mohrman: I would like to ask Mr. A. C. Cummins, Chairman of the A. I. & S. E. E. Standardization Committee, if there is any likelihood of our society standardizing brushes.

Also if our society would decide to standardize brushes would that interfere in any way with our present A. I. & S. E. E. Standardized Mill Type Motors.

A. C. Cummins: It is more complicated for the A. I. & S. E. E. to standardize brush sizes than it was to standardize on the mill type motor. In the case of the mill type motor, there are few users outside the steel industry and the Association could select standards fitting their purpose without fearing that they would tread on the toes of other users, and for his reason they could properly deal directly with the manufacturers of this equipment. In the standardization of carbon brushes on the other hand, the steel industry does not represent a major portion of the users. Any standardization program to be satisfactory to the manufacturers must be so consummated that all users have a voice in determining what is necessary to meet their requirements. For this reason it appears that the Association cannot act as an individual agency in the brush standardization program, but must co-operate with some other organization better fitted to fully represent both manufacturers and all users. It would be my idea that the proper agency for handling this work would be the American Standards

Association recently formed from the old American Engineering Standardization Committee.

As to the second question, namely, whether standardization of motor brushes would affect the dimensions of the standardized mill type motor already selected by the Association, I would say that it is not possible for me to conceive of any changes in brush dimensions which would affect the external dimensions of a motor of the mill type, and that the Association Standardization Committee can see of no reason for making any changes in the standardized dimensions published in June, 1928 on account of changes in brushes, or for that matter, for any other reason. I believe it can be said that the dimensions published in June represent the last word that we have to say on this subject for a number of years in the future.

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*Rolling Mill Practices— Germany, Spain, Russia**

By F. L. ESTEP†

I have just returned from a trip to Russia, the third of which I have made, having gone over originally three years ago this winter in connection with an iron and steel project, at which time I visited several of the plants then in operation and studied what they had, which wasn't much everything considered, but I did see some unique things which I will touch on later.

I might say that the steel plants in Russia were originally practically all owned by outside capital. I am speaking primarily of South Russia. There were French, Belgian, German, English, Polish companies, and one plant only in South Russia which was practically all Russian capital, so when the Revolution came and the government took over all the plants and put them into a combine as a trust, they had to take them as they were, and many of them had been run over by the Revolutionary armies and shot to pieces.

The equipment existing in South Russia today in the mills is very antiquated. It was all installed previous to 1914, and they have run all the different plants to the limit in order to get production. They have maintained them very poorly.

The steel which they make and roll for all purposes is exceptionally good in spite of the fact that they are handicapped with high sulphur coal and coke. They have plenty of good cheap manganese and they make a very clean steel by usually taking off two slags from their open hearth furnaces. About 95 per cent of the total steel which I saw being rolled in nine plants was rolled direct from the ingot. In other words, they rolled plates direct from ingots; they rolled their skelp for larger pipe; they rolled wire, shapes, etc. About the only thing that was used or handled much as we handle things here was making sheets from sheet bars.

They make ingots as small as 6 poods, about 215 pounds, up to 5 or 6 tons for rails and some heavier ingots for plates.

There are one or two operations which I believe would be of interest. One is a rod mill which I saw operating three years ago last December at Dnieprovski. This was a German designed mill consisting of three stands roughing, three stands intermediate, five stands of first finishers, and four stands of second finishers, rolling 4½ mm. to 5½ mm. rod direct from an ingot about 7-inch square butt, weighing 12½ poods, or about 450 pounds, and there are no mechanical contrivances whatever. It was rolled in twenty-three passes.

They were sticking at the time I was there, on the finishing stand, with rolls 265 mm. diameter. The actual revolutions which I took myself were 594. That is a sticking speed on the last pass of 1510 feet a minute which is higher than in this country and calls for very expert manipulation.

While we were there we got them to speed up the mill to see what it would do and over a period of fifteen or twenty minutes they pushed the mill up to 20.6 metric tons per hour which is quite good, about 250 tons per twelve-hour shift. They did that without making a cobble.

In this same plant they had two quite modern merchant mills that were built in Riga from German design and installed some time about 1913. These were the only two merchant mills I saw in Russia that had cooling beds. They were much like our horizontal beds, with belt-driven roller runs, maple leaf or clover leaf manipulation on a horizontal bed. It was not very long but it was taking care of the product.

One interesting thing I saw on the rod mill and on one of these two merchant mills, and later on found in use in Germany, was a mechanical repeater for comparatively moderate sizes, going from squares to oval and oval to squares in one stand of rolls. For instance, the first time I saw this I didn't know what happened. I looked around awhile and found out. They were taking a billet about 2¼ inches square and entering it on the bottom. It came up between the middle and the top 16½ inches distant and was immediately sent into the bottom 13½ inches distant. This was on a mill with a delivery speed of about 800 feet per minute. I watched this five hours during two or three days. I have yet to see a cobble. Nobody paid any attention to the device. There were three passes in one stand of 450 mm. rolls, or 18 inches in diameter, and taking reductions of over 40 per cent per pass. I actually

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found the same thing on one of the rod mills in Germany.

I should like to say a few words about the manufacture of Russian Roofing Iron by the Ural process. Roofing iron in Russia is of one size only, 28 inches by 56, of various weights, running gauges from 18 to 28. They pay no attention to gauge. They go by weight per sheet.

I saw this operation in one plant only in South Russia, namely at Brianski. The great majority of it is made in the Ural Mountain district and from that place it got its name.

There are only one or two interesting things about it, one of which is a method of rolling which I will try to describe briefly and one interesting thing in connection with that was the speed at which the rolls are operated. Roughing and finishing were done on one stand of rolls. The rolls were 570 mm. in diameter and by my stop watch they were rotating 58 revs. per minute. That is a surface speed of 317 feet a minute, which is equivalent to over 40 rpm of one of our ordinary sheet mills with 30-inch rolls, and these men were working at that speed every day.

Russian Roofing iron has a very high polish. It is finished in packs of four. Bars are roughed in pairs and matched into fours quite a bit as it is done in this country. In the roughing of each set of pairs after the first pass and afterwards during the process of finishing, the screwdown man throws very fine sawdust which comes from some hard wood up north. He throws it between the sheets which lifts the scale and tends to get the delicate brown color. The pairs are roughed out to about 38 inches long and packed in fours, reheated, and then finished. They are scaled very highly in the furnace. I think the scale loss total must be 5 or 6 per cent.

When a pack of four sheets come from the furnace for finishing, the roller takes his tongs and separates the sheets, exposing the front half of each sheet. The top of the front halves of sheets Nos. 1, 2 and 3, and the entire top of the top sheet are coated with sawdust. The pack is closed up, even on the front, and as the roller lifts the back end of the sheets, sawdust is thrown between each sheet on the tail of the pack. The pack is given one very heavy pass, stripped open by the roller, sheet by sheet, and redusted by the screw down man. This is repeated for 4 or 5 passes, and then the pack drawn to length, by eye only. No rule is used.

The packs are slammed through at terrific speed, about twenty-five packs per cycle, and then roughing begins again.

Immediately these sheets are finished off the rolls, they are sheared roughly to over-length and overwidth. The sheets are then packed about three-quarters of a ton in a pile, protected top and bottom with old sheets and wrapped up, put in a crude furnace and given a very high anneal. When the pile of sheets, which is about ten or twelve inches thick, comes out of the furnace, it is put on a large anvil block underneath a heavy lever hammer, operated by steam. It has a stroke of about 80 per minute, and the peel is slightly oval, so when it makes a dent on a sheet, it will be a comparatively light pock mark, say 1½ inches wide and 3 or 4 inches long. This pile of hot sheets is shoved around with crowbars and hit here, there, and everywhere. Then the pack is shoved off the block and repacked with other sheets on top, and that is repeated four or five times. The sheets are pounded until they are quite cold, sheared to proper width and length and then weighed, one sheet at a time and put in different bins, the classification being by weight only.

The sheet when finished is wonderful looking. It has a brownish color. You can stand back and look at the indentations all over it and put your hand on them and you can hardly feel them. They are in there just the same. That helps to give the polish. The operation is very expensive in that the tonnage is low as compared to ordinary sheet rolling, but there is rather a high premium for these same sheets in Russia. The premium three years ago, was 21½ cents a hundred American pounds.

The hot mill crew was eleven men total, including the furnace.

Those are the only two things, to my mind, that stick out from what I have seen in Russia in regard to process. The sticking speed on the rod mill, which is abnormally high, and then the speed of the rolls on which they are making the Russian roof iron.

I should like to talk a few minutes about one of the plants in Germany, the August Thyssen Hutte plant at Hamborn. It is now part of the German Steel Corporation. They have two blooming mills the same size, one started in 1923 and the other in 1928. There are two high reversing, with rolls 1180 mm. diameter, and pinions 1320 mm. diameter or about 52½ inches. These two mills are used for rolling of ingots weighing 4.5 to 4.65 tons, rolling them into billets, into rails, metal railway ties, shapes, and other finished products.

The second blooming mill was added with new soaking pits in order to increase the capacity of the plant in the rolling end of the game, and they have since put in some finishing mills, which I will speak of later, in order to use up the semi-finished steel.

I might say first of all that the total capacity of the plant today in ingots is about 2,100,000 tons. Seventy to 80 per cent of that is Thomas process steel and the rest is open hearth. They originally had five converters, thirty tons each. They had altered one on the same centers to 42 tons. I saw it working in September, and they are going to change the other four to forty-five tons each and blow forty-five tons at a heat.

The old blooming mill is served with sixty-four soaking pits without gas, and twenty soaking pits with gas, all single ingot pits. They claim that their soft steel is soaked only in the unheated pits, but that rail steel or special steel, after being in the unheated pits about two hours, is transferred for approximately thirty minutes into a heated pit for further and additional heating on account of the quality of the steel.

I must say I have never stuck around the mill long enough to prove how long a certain ingot would be in the pits, but the time, based on timing in the rolling mill ingot to ingot, is about an average of 2.3 hours per ingot, taking 40 per cent of rail steel and 60 per cent of soft steel. The new blooming mill has one hundred soaking pits total, sixty of which are unheated, and forty have gas. In other words, they have raised the percentage of pits total that are equipped for gas as compared with the old mill, showing two things: First of all, they anticipate rolling more rail steel and, further more, have

found they get better results in many cases by additional heat other than letting an ingot soak without any gas.

One very interesting thing in connnection with the new blooming mill arrangement, soaking pits, and steel-making department is this: When a converter is poured, the metal is taken up to a pouring stand where there is a stripper, poured and immediately stripped. Then to convey the ingots into the soaking pit building where the single hole pits are arranged at floor level covered with a low crane which lifts a cover, takes it off of this pit and puts it on so that they have a 10 meter diameter rotating device consisting of four arms; on the end of each arm is a basket or crate and when an ingot is stripped, it is immediately put in this and revolved 90°, then another 90°, and when it gets to the second 90° or 180°, it is lifted out.

From statements made to me, checked by observation on two trips, they claim with a thirty-ton blown heat, the time does not exceed twenty-one minutes from the time the vessel is finished poured until the last ingot of that heat is in the soaking pit. That conserves their fuel. In the first place there is no fuel on 60 per cent of the pits. This is only possible with Thomas steel where you can work hand to mouth, and you can't do it with an open hearth layout where you have to transport your ingots first from the pouring platforms to the stripper and then to the soaking pits. That one point, namely why they have a low fuel consumption in this plant is a thing Russian engineers couldn't understand as compared to the United States. That is, why you couldn't roll Open Hearth ingots with almost zero heat in a modern plant making 800,000 or 1,000,000 tons, which are all poured in a plant we will say one-half mile away from the soaking pits.

In regard to the amount of fuel required in these particular two sets of soaking pits with steel coming as I have described and most of it very, very hot, they get away with about 3.6 per cent of the weight of ingot in coal equivalent of straight blast furnace gas. The coal equivalent is based on 7000 calories per kilogram of coal. You can convert that into B.t.u.'s. That is not so low when you consider that they only heat about 40 per cent of the steel. It is not so good as it appears on the first glance. They are using straight blast furnace gas with both gas and air regenerated. They claim that there have been periods of a few days at a time when very little open hearth steel was coming to these pits, or when they were running practically 100% Thomas, the fuel consumption in coal equivalent was as low as 2.1 per cent of ingot weight. That is in terms of ingots rolled, not blooms.

If you ask them what is the capacity of the blooming mills, their answer is 3300 tons of ingots per twenty-four hours. I have put a stop watch on the old mill, on five different visits, catching four or five ingots at one visit, to eight or ten on some other. The average of my observed time, ingot to ingot on these different trips, covering I would say a grand total of thirty, forty, or fifty ingots was one minute and forty-five seconds. The maximum observed time that I ever took was two minutes and five seconds and the lowest one minute and thirty-two seconds.

I could not account for the differences in the time by watching the mill. There appeared to be no marked delays, but there were those little things that add up. If they rolled 3300 tons in twenty-four hours, taking the ingot weight average of the two weights I have given above, the mill must roll one ingot every two minutes, average, for twenty-four hours. This would mean a sustained rate for 24 hours at 87.5% of my observed average times of 1 minute, 45 seconds, for a few ingots at a time, with no apparent delay. This ratio is very high, and points to a very highly sustained efficiency of operation, or to the question of accuracy of the figures.

First of all I should like to say this: We are claimed to be very extravagant in our mill layouts when it comes to spending money. In this mill, in front and back of the blooming and finishing trains, and back to the finishing department, you can walk on the cast iron floor plates which are at table level and cover up everything. They have nine bays at right angles for handling the material rolled on the finishing mills, of which there are two in line. One is 950 mm., and the other 750 mm.

Heavy shapes are rolled on the larger mill, including rails and metal ties. Metal ties which are very difficult to roll on a mill and take a tremendous lot of power. They straighten their rails on a roller straightener. Probably 95 per cent of the total straightening required is done on the roller straightener and very little gagging is needed.

One particular thing I wish to speak about that I have seen made here is a metal sleeper or metal railroad tie, which is very commonly used in Germany and many of the foreign countries where wood is scarce or where, for instance as in India, the ants eat up the timber as fast as you put it in the ground.

In England they make these so-called metal ties they roll a flat on a mill, shear it up into lengths, and then reheat every sheared piece in a furnace, giving one operation in a press, reheat and give another finishing operation in a second press. From the ingot the piece has probably had a total of four heats.

I happened to be in Paris when an Englishman there was talking to a friend of mine and he wondered why England couldn't compete with Germany on metal ties. I asked him if he had visited the plant at Hamborn and he said no. Then I told him about it.

At Hamborn they take a 4.5--ton ingot and roll it into a slab in nineteen passes on the blooming mill, crop it, convey it to the 950 mill and finish in 9 passes from the original heat, saw it in two, and start it in two parallel streams on a divided roller run, each stream going to a shear which cuts off the pieces in lengths and each feeds a press, and each press makes one completed sleeper, fifteen a minute. They immediately pass out of the presses, go through the oil tempering bath, come up under a series of spray pipes and are cooled. Then they are carried by cranes to the inspection beds.

On this basis of converting an ingot into a finished metal tie, coupled with what I have told you about getting the ingots into the soaking pits and into the mill, it is entirely possible to ship a carload of ties in less than six hours after a converter heat was poured.

It is not possible to do this in England and it is hardly possible to do it anywhere else. I am afraid my friend in Paris didn't believe what I told him.

At this same plant they have put in some addi-

tional finishing mills over in another department away from the two blooming mills which I have described. They have a smaller blooming mill, the exact size of which I do not know, an old mill, at the present time rolling practically all of the open hearth steel from another set of pits and converting it into billets to be reheated. They have in particular three new sets of finishing mills, one of which is a rod mill consisting of six stands of continuous rolls feeding three intermediate stands, and then four first finishing and three second finishing stands, making a total of sixteen passes from a billet about 3¾ inches square to a 4½, 5 or 5½ mm. rod.

This mill is very fast and the finishing stand has five reels. This particular mill has been in operation now for something over a year and has proved quite successful. The billets are heated in two very long continuous furnaces. The length was given to me as 25 meters, which seemed pretty long, but I had no opportunity to measure them. That would be 80 feet plus, and that is a long furnace.

Both of these furnaces use straight blast furnace gas and the air only is regenerated to a temperature of from 1000° to 1200° Centigrade. Their fuel consumption per ton of billets on these particular set of furnaces is 540 cubic meters of blast furnace gas at 1000 calories per cubic meter. That is 540,000 calories, or about 2,100,000 B.t.u per ton.

They have two merchant mills. The light one, which I will describe first, has been in operation since last summer and they have learned how to handle it fairly well. It has a continuous roughing train, parallel and adjacent to the continuous roughing train of the rod mill which I have just mentioned. They are side by side. The rod mill starts over to the left and the merchant mill to the right. The latter has six roughing stands, three stands intermediate, five stands finishing train equipped with single horizontal mechanical hotbed, a hotbed of quite good design. This mill is also served by two furnaces. One uses blast furnace gas straight, with air and gas both regenerated at the end of the furnace in a big checker chamber to a temperature of 800 degrees Centigrade. The second furnace or newer one is slightly longer than the one just mentioned. It burns coke oven gas and blast furnace gas as a mixture with neither air nor gas preheated.

That is the type of furnace that will serve the heavier merchant mill. One was built when I was there. I have the word of their fuel engineer that the consumption per ton of billets on the one furnace for the light merchant mill using coke oven gas and blast furnace gas as a mixture at about 2000 calories without any regeneration was no more than in the furnaces where the air was preheated and no more than in the furnace where both gas and air were preheated.

Their other new mill is a heavy merchant mill which is unusually laid out. It has not yet been properly started in operation, or at least it had not when I saw it the last time in November. They had a good deal of trouble learning how to run it. They tried to do too many things on it. It consists of six stands continuous and off to the side at a considerable distance are three stands with heavy mechanical repeaters to transfer a piece from the six-stand continuous mill to the front side of first stand of the intermediate, from that to stand number three, and then repeated through stand number two Stand number two is in line with Stand number one of the second finishing train. There are five stands in the first finishing train and three in the second. One is for light material and one for heavier material, and each train has its own horizontal cooling bed.

As near as I could make out without anyone's being able to tell me, they figured perhaps that this one set of six stand continuous could serve either way and, that they could be changing sections on one while rolling on the other and not have any lost time. I couldn't get any verification of that idea, but otherwise I couldn't see any reason for the layout.

This particular mill was started only in September and they have not yet learned how to run it. It will take them another year.

I might say a few words about what I saw in Spain at two or three of the plants. At the Altos Hornos plant in Bilbao there are two works of this company situated a little over a mile apart on a river, each with blast furnaces and coke ovens. One has an old open hearth and the other a Bessemer and both have mills. One has tin mills.

One plant, Baracaldo works, has a new Blooming mill which has been in operation only about a year, or perhaps I should say "semi-operation," because they haven't steel enough for it at the present time. They have built a new open hearth plant consisting of three 75-ton open hearth furnaces located between the Baracaldo and Sestao Works. It is going to be very hard to serve this new open hearth with materials and metal, and it is going to be difficult to get the ingots to the new bloomer because, although they are situated not far apart, they are on different sides of a street and are practically at right angles to each other.

This new mill, which is the newest blooming mill in Spain, has rolls 1041 mm. in diameter. It has an A.E.G. motor about 18,100 maximum h.p., 1,590,000 foot lbs. maximum torque. It operates on a voltage of 700.

In order to get in this blooming mill at all and get some soaking pits in front of it and a finishing mill back of it, they had to put it down in the corner of the old works, practically up against the river. They have it in a location now where it can never handle the tonnage it should so far as the mill is concerned. On account of this same street I mentioned before, they could not put the Illgner set in any possible proper location to the motor, so the Illgner set is in a building across the street and the length of copper leads from the motor generator set to the blooming mill motor switchboard, is 92 meters, which is about 300 feet.

This mill, during the time I observed it in operation, was serving a new 850 mm, 2 high-reversing combination rail and structure mill which had been installed about the same time the blooming mill had been installed. They were rolling rails. The steel they were rolling at that time was Bessemer steel and they were having bad luck with it throughout, one ingot out of every three, and in some cases practically every other ingot was cracking badly at the blooming mill and they were rolling it right on into rail, finishing a whole ingot as one rail at the original heat.

At the time I was there this mill was rolling at the rate of only 36.5 tons an hour. As I said before,

the mill is capable of much more and so is the motor, if it could be accelerated faster, but they would be up against it in my opinion if they tried to increase production above 60 tons an hour, first of all for soaking pits, and second, on how to get the stuff away. The solution some day will be to take the mill up and locate it somewhere else.

They have no cambering machine here for rails and I found that to be the case down at Sagunto. They never tried a cambering machine at the plant at Bilbao. F. C. Roberts laid out the plant at Sagunto in 1918, and he furnished a cambering machine, but they never had anybody who could run it or turn the rolls for it, so it has been thrown into the discard and is said to be a fizzle. So, in both of these plants where the only rails in Spain are rolled, they go from the mill as they come and cool as they will and then they have to gag them straight.

At the plant in Bilbao they have installed a roller straightener but it was not operating in July when I first saw it nor in October when I saw it last and I think they are afraid of it.

At the other works of the Altos Hornos plant in Bilbao they have two fairly modern finishing mills laid out by German engineers and built in Germany, one continuous mill of six stands receiving billets from two furnaces and serving both mills. The layout is such that in the future a second set of continuous rolls can be put in and have each mill independent.

One mill is 280 mm. and the other was originally built for 365 mm, but was converted into 420 mm. They have insufficient power on this latter mill and, furthermore, the lowest speed is so high that the men cannot handle heavy material and they are now compelled to face the installation probably of a slower speed motor of approximately 50 per cent capacity.

One of their troubles is that they are trying to roll about a 4¾-inch channel on this mill and that takes a lot of power and is causing them to go up in roll diameters and their speed for that section is too high. Neither one of these mills have any tables. They are hand operated.

The other mills in the Altos Hornos plant, as well as the mills of practically all of the plants in Spain except those in Sagunto—I am talking of the merchant mills, the smaller mills—are quite old.

In the Sestao works at Bilbao there was a 650 mm. (26-inch) motor driven mill where they were rolling sheet bars, taking an ingot approximately 12 inches square. This mill consisted of five stands. The speed on the mill was so high that when the piece came back from pass number two on the top and from number four on the top, one man on the tongs and four men hooking up would be thrown at least ten feet from the mill trying to stop it; therefore, to hold it down at times they threw in a big water rheostat, and then cut it out and let the mill speed up. At the same time the motor was not of sufficient capacity to drive the mill when rolling on the last three passes. It would almost die on the job. Furthermore, although they were rolling tin bar, they never had heard of putting water on the rolls and had no idea of using chilled roll for the last pass, and over in the tin mill I saw bars that I could take a knife and pick up a scab off them half as big as my hand and on about every truck-load, if you looked at the shear ends, you could find bars where you could run a knife blade in. They were trying to send a bar over to the tin mill about 93 or 94 per cent yield of ingot, which was entirely too high.

One day they were rolling on this mill with thirty-four men outside of the furnace men. There were nineteen on the back side and fifteen on the front side and about five fellows bringing ingots on buggies from the furnaces.

The same sort of layout is true in some of the other old mills and I pointed out to one of the leading directors of the company where if they had one, say 24-inch mill of proper layout, they could shut down or throw away five mills that they had and cut the labor force to 20 per cent for the same total number of tons, and cover all the range of sections, and probably cut the power and fuel bill to about 65 per cent. They have this under consideration, but I don't know whether anything will ever happen about it.

I might mention one thing about tin plate. There are two tin plate plants in Spain, one at the Sestao work of Altos Hornos, and another owned by the Basconia Steel Co. The system under which the mills operate is the same as that in Wales. They make a pack from a single sheet bar about ⅞ inches thick, beveled edges. The widest width they roll is about 27 inches. They cannot get the men to go beyond a certain pack weight, the exact limit of which I have forgotten but it figures about 27 inches wide, 8 sheets of 31-gauge, say 60 inches long.

The roughing is done exactly the same way as in Wales. The roughers take a pair of short tongs and pull the screws with first their right and then their left hands. The big difference between these two plants in Spain and the plants today in the Welsh industry lies in the fact that in Spain you can only get the men to make so many packs to a day's work and the equivalent of that is 40 base boxes per mill per shift. When they make that amount they go home, and if they get through in five hours, they shut the mill down and let the next crew warm it up. The managements have tried to induce the men, not only at the same rate of wages, but on an increasing scale, to make more boxes. They won't do it. In Wales they make 63 to 65 boxes of the same stuff in eight hours.

One plant is using all open hearth steel and the other all Bessemer steel. In the plant using Bessemer steel they tried open hearth steel but got into a lot of trouble with stickers. This trial was made between my two visits to Spain. I had made a suggestion about cutting some of the phosphorus out of the bars and putting a little more silicon in and they tried that and made about 20 per cent of blisters because as I found out afterwards, they put the Ferro-silicon in the ladle after the heat was tapped instead of putting it in the furnace. They didn't get any results from it although the steel analyzed all right.

Now just a few words more about the Sagunto plant. This plant consists of two blast furnaces, six open hearth, as I remember, a blooming mill, combination rail and structure mill, a plate mill, and one merchant mill. The plant is quite well laid out and it is the only one of all of the plants in Spain that can be extended for increased production at low operating cost without a lot of trouble.

The plate mill is not good. It was bought secondhand. They have never used it very much and their warehouse or finishing end is full of bad plates today that have been lying around there for several years. They are making quite good rails and are up against the same thing as at Altos Hornos when it comes to straightening the rails. The rails are very crooked off the cooling bed and the cost of gagging them and getting them straight is very high.

They looked on their merchant mill as more or less a joke. I didn't see anything particularly wrong with the mill. The mill is there and it can be made to operate. I think the trouble is with the operating crew. I saw them make a bad cobble through plain carelessness, and no one from the boy who pulled crops from the shear, up to the boss in charge thought anything about it. They took eighteen minutes to get the cobble out and when they went ahead and very shortly made another cobble.

There is just one other thing I might mention which might be interesting, which I ran across in Sweden at one plant. This has to do with the percentage of rail seconds. Some of you connected with rail-making plants in this country know what the seconds run, some of them quite high, some a little better. In some plants the blooms are rolled direct and some are reheated, and you will find all sorts of percentages in seconds. There was a plant in Sweden which made about 50 per cent of charcoal pig iron in the ordinary charcoal furnace with hot blast, and the other 50 per cent from electric charcoal furnaces. Then this was blown in converters and made into steel. They take an ingot and roll it direct into rail and I saw their percentage record for seconds for the year 1927 and it was 1.84 per cent on about 100,000 tons of rail. The point of that is the low percentage of seconds.

In one plant in Spain they claimed their seconds were about 7 per cent. Judging from the rails that I saw in transit to the finishing department and several thousand tons lying in the finishing department, I think it was more nearly 10 per cent.

The Selection and Application of Direct Current Brushes

By R. H. NEWTON*

IN the application of brushes for commutating apparatus, it is obvious that no clearly defined rules governing the selection of brush material can be laid down. Brush selection today is based on results obtained by the use of elaborate brush testing equipment now used by the manufacturers of this type of apparatus, together with the years of experience obtained on machines in actual service. The matter of brush selection for commutators has been a serious problem ever since this type of equipment began to be used. The adoption of compensating windings on direct current generators and motors, and commutating poles on synchronous converters, has made it possible to greatly reduce the weight and cost per Kilowatt over that which prevailed prior to the advent of these improvements in this class of apparatus. This progress in the art has made possible the reduction of the number of poles required for given Kilowatt ratings, with correspondingly increased RPM. This increased speed, together with more exacting service demands, has kept up a series of difficult problems for both the machine and brush manufacturers, as well as the users of this type of equipment.

SELECTION OF BRUSH SIZE

The brush size required to give the best performance on a direct current machine is dependent on such design factors as: Main and commutating pole field shapes, commutating zone, and the resultant armature reaction. For any machine design, therefore, the design engineer can either work out his design to conform to a given brush size, or can go ahead and complete his design, regardless of the size of brush to be used and then specify the brush size necessary to suit the design and which will give satisfactory performance. Obviously, the former method of procedure involves more of hardship on the Design Engineer than the latter, if competitive apparatus is to result, both with respect to performance and cost. The results of such efforts, however, are readily appreciated by the ultimate consumer in helping to keep to a minimum, stock sizes of brushes to be carried for replacements. This reduction in brush size requirements by the machine manufacturer is also of important interest to the brush manufacturer. Sincere and whole-hearted efforts have been going on now for some time by the manufacturers and users of this class of equipment to reduce the standard sizes of brushes required to a minimum. The Westinghouse Company have long realized the importance of this matter of keeping the number of brush sizes to a minimum. Efforts along this line have resulted, we believe, in their now holding the distinction of requiring probably the least number of grades and sizes of brushes of any manufacturer of electrical equipment, considering the diver-

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sity of sizes and types of commutating apparatus manufactured.

The Power Engineering Department's line of commutating apparatus comprise D.C. motors and generators and synchronous converters varying in capacity from 100 KW to 6000 KW, and from individual commutator voltages of 125 to 1500. This is a ratio of 60 to 1 in capacities and 12 to 1 in voltages. In spite of this wide range of ratings and voltages, only four sizes of brushes are used, namely ½", ¾", 1", and 1¼" thick. All brushes have the standard width of 1¾". The ¼" thick size of brush has more recently been superseded by the use of a double ⅝" thick size for reasons of commutation improvement, so that at the present time, Power Division requirements for their entire line of apparatus still require the use of only four sizes of brushes.

The Motor Engineering Department's standard line of SK motors and generators vary in capacity from 1 HP to about 200 HP and voltages per individual commutator of from 7½ to 750. This is clearly a greater ratio of ratings and voltages than used on Power Division apparatus and comprises as 200 to 1 ratio in capacities and 100 to 1 ratio in voltages. In spite of this very large range of ratings and voltages, only fourteen sizes of D.C. brushes are required for the entire line.

The Motor Engineering Department's standard line of MC motors, built especially for mill applications, comprises ratings between 6 HP and 275 HP and voltages of 230 and 550. This line of machines has been standard with our Company for the past eighteen years and requires the use of but eight sizes of brushes.

From the above references it will be seen that only 26 sizes of brushes cover the requirements for Westinghouse direct-current apparatus applied to all classes of mill, central, and sub-station service. This number of brushes covers the requirements for apparatus varying in capacity over a range of 6000 to 1, and in voltages per individual commutator over a range of from 200 to 1. The efforts that have been put forth by our engineers, making possible the use of so relatively few number of brush sizes for such a diversified class of commutating equipment, have not by any means stopped at the figure of 26 sizes. In spite of the progress along this line already obtained, a study of the possibilities of further reducing the number of sizes will, no doubt, result in considerably reducing the present requirements still further.

Selection of Brush Grades

The selection of brush grades for commutator use involves both electrical and mechanical considerations depending upon the characteristics of the machine in question. From the electrical standpoint, any brush to be suitable must have proper contact drop to keep the short circuit currents under the brush well within control with a minimum brush I^2R loss when the machine is operating under normal conditions. In addition to this, it must also have sufficient current carrying qualities to prevent overheating. From the mechanical standpoint, the peripheral speed of the commutator, angle of the brush holder, and whether commutator mica is undercut or not, are of importance as factors to consider in the selection of a brush with proper characteristics to give long brush life with low friction losses and at the same time ride smoothly on the commutator, so as to give the minimum amount of noise and vibration. These electrical and mechanical characteristics must all be given consideration in the selection of brushes for any given machine, as best commutation and all around satisfactory operation is to be obtained with a minimum amount of maintenance and up-keep expense.

The service required of a machine is another important factor in deciding the proper grade of brush to select. For instance, railway service, with a load factor of 65% during twelve daylight hours of service and 20% during 12 hours of night service, will obviously permit greater latitude in brush application for a given machine than where the same machine is applied to electrolytic service with a 98% load factor over the entire twenty-four hours of the day.

It must be understood that every application of brushes can be decided only after consideration of all the merits and characteristics involved in each individual case. The following tabulation will be found useful as a reference in approximating most of the average cases:

Carbon Brushes are suitable for use on non-undercut commutators, with commutator speeds up to around 3500 feet per minute and brush densities not exceeding 35 amperes per square inch.

Electrographitic Brushes are adapted for use on undercut commutators with commutator speeds up to 5000 feet per minute, and brush densities around 50 amperes per square inch. On normally loaded apparatus such as for railway service, with usual load factors, this grade of brush is applicable on commutator speeds up to 5500 feet per minute and densities of 55 amperes per square inch. Where operating conditions permit the use of this grade of brush, it is to be preferred because of:

(1). Lower initial cost.
(2). Long life.
(3). Minimum commutator wear.

Graphite Brushes are good for use only on undercut commutators with commutator speeds, running up to 6000 feet per minute and above, and brush densities of 60 and 65 amperes per square inch. It is usually necessary to use this type of brush on application where severe or unusual operating requirements have to be met such as are obtained on electtrolytic work, cement plants, or heavily unbalanced Edison three-wire systems.

DIRECT CURRENT BRUSH ADAPTATION

After selection, the success or failure of any grade of brush may be directly due to any one or more of the following causes:

1. Correct Commutating Pole Field Air Gap

The commutating pole adjustment to give the best commutating conditions, is made at the Works, and in general, no reason for changing it after the machine is installed will arise.

2. The Angle at Which the Brush Is Set

It is true that certain types of machines which are subject to frequent reversals such as mill motors, may be said to automatically fix the brush position as radial or practically radial. This does not mean, however, that if set at some angle, say ten or fifteen degrees, or even a greater angle, that the aver-

age results might not be as good as with a radial setting.

When machines are not subject to reversals, the proper angle will depend upon:

(a.) Whether the rotation is against the heel or against the toe of the brush. (The toes is the point of the brush on the side having the acute or small angle; the heel is the side having the large or obtuse angle. This is independent of rotation). If against the toe, the angle should approximate 35°. Above 3'5°, the toe becomes very sharp and mechanically weak. This point, therefore, must be guarded against. If against the heel, the angle may be from 15° to 25°.

(b). Upon the friction coefficient of the brush. This factor is decidedly variable, being influenced not only by the inherent characteristics of the brush, but also by the glazing of the contact face of the brush, the varying brush temperatures due to load and spring pressure, and the condition of the commutator—whether smooth or undercut—hot or cold—or in good, poor, or bad mechanical condition.

3. Brush Holders

Generally speaking, brush holders of the sliding shunt type, arranged for mounting so that minute parallel or radial adjustments can be easily made, are preferable. Such a holder is readily suited to accommodate a brush lifting mechanism, as well as flash guards, when either or both of these features are required.

4. Brush Arm Spacing

The relative spacing of brush arms around the commutator as determined by the edges of the brushes, must be uniform. The difference in spacing in this respect should not be more than 1/16".

5. Brush Pressure

This depends on the characteristic of the brush, peripheral speed of the commutator, and the mechanical condition of the commutator. Pressures generally used are from 2 to 2½ lbs. per sq. in. of cross sectional area of the brush. If there is a tendency for the commutator to burn, this can at times be corrected by increasing the pressure, and thereby increasing the abrasive effect of the brush sufficiently to scour out the burning and maintain a polished surface.

6. Mixing Brushes

Brushes having different characteristics should not be mixed on the same arm or on different arms of a given polarity of the same machine. In exceptional cases, the use of brushes of one type on all the arms of one polarity, and of a different type on all the arms of the opposite polarity is permissible. Such an application is desirable when both abrasive and lubricating action is required, or when the electrical characteristics under the brushes differ greatly on arms of opposite polarity due to a lack of electrical or mechanical symmetry in the design of the machine. This lack of symmetry may be such as to result in brush drop variations between brushes of opposite polarity of sufficient importance to warrant the use of brushes having different characteristics on the opposite arms.

7. Staggering Brushes

Staggering is done to cause the commutator to wear evenly and should be done in pairs of arms (in alternate arms); i. e., one positive arm with one of its adjacent negative arms should be set, if possible, to the right or left of the initial pair, half the distance laterally between brush centers. The third pair should trail the first pair (the fourth the second, etc.). With this arrangement, any action tending to take place under brushes of one polarity will be neutralized by the brushes of opposite polarity being directly in line with them. This arrangement gives a more uniform wear over the entire face of the commutator, and thus permits the satisfactory operation of certain grades of brushes where grooving trouble may have been experienced with the incorrect scheme of staggering.

8. Shunts and Brush Caps

Soft brushes require protection from the wearing effect of the tension spring hammer. This protection may consist of either a metal cap which covers the entire top of the brush, or merely that part upon which the spring presses.

It frequently happens that the resistance between the brush and the brush holder is less than that between the brush and the shunt. As a consequence, the function of the shunt is usurped by the holder and the tension spring, resulting in burning of the brush faces and in the destruction of the spring.

This indicates that the shunt attachment is defective. The ultimate for shunt application is a combination of brush, shunt, and terminal which will cause the shunt to carry all current between the brush and machine terminals, and unless this consummation is realized, manufacturers and users of electrical apparatus must expect to pay liberally, not only for damage to their brushes caused by the current by-passing the shunt, but also for freequent renewals of their brush holders and brush pressure springs.

If shunts are to be subjected to the effects of chlorine or other deteriorating gases, they may be protected by a tinning process which in no way affects their flexibility. The strands of the shunts should be pliable and flexible. If mechanically stiff and brittle, they break and may cause short-circuits between the brush rigging parts. Practically all brushes nowadays are supplied by the brush manufacturer complete with shunts and clamps.

INSTALLATION AND MAINTENANCE OF BRUSHES

Properly selected and applied brushes may fail on account of neglect, while improperly selected and applied brushes may render acceptable service if given intelligent care. Proper care of the brushes and brush rigging is a fundamental of good commutation and of a prolonged life for both commutator and brushes. Operators of electrical apparatus are directly responsible for the majority of their commutating troubles, although the machine manufacturer is frequently held to account. There are, on the other hand, a few who give such superior attention to their brushes that inherent brush and machine evils are rarely permitted to assert themselves. The following practices will more than justify the effort:

1. Keep the brushes clean. All brushes get dirty,

become coated with carbon dust which bakes between the brush and brush holder and thereby binds the brush in the box. This frequently results in broken brushes, correspondingly poor commutation, resulting in necessity of concluding with either a grinding or a turning of the commutator.

2. Keep the spring pressure uniform, otherwise selective commutation results. This causes rapid deterioration of the overlooked brushes and holders with its subsequent poor commutation and high maintenance costs.

3. Fit the brushes to the commutator properly. Great care should be exercised in grinding in or sandpapering brushes. The faces of the brushes should be carefully fitted to the curvature of the commutator. This can be done by putting the brushes in the holders and drawing a long strip of sandpaper under each brush while pressing it firmly against the commutator. The sandpaper should cut the brush only on the forward stroke and in the direction of normal rotation.

4. It is important that the brush holders be the proper distance away from the commutator. This distance should not exceed 1/8".

5. If the brushes are copper-plated, the plating should not be allowed to come into contact with the commutator. This means that as the brushes wear, the copper coating should be scraped back and not allowed to extend below the brush holder box.

6. If the toe of the brush is very sharp, it is good practice to round off the knife edge. This reduces breakage and prevents gouging into the commutator.

The following more important terms used in connection with brushes are given for reference purposes:

Contact Drop—The drop between the brush and the commutator. The contact drop differs with different materials, different brush pressures, and different loads; presupposing that the brush and spring pressures are identical, the contact drop between the commutator and positive brush differs from that between the negative brush and commutator on any given machine.

Brush Friction—The co-efficient of friction depends upon the brush material, brush angle, and commutator speed. With a given material and brush angle, coefficient of friction increases with load and brush pressure, and generally speaking, decreases with increased commutator speed.

Specific Resistance—The ohmic resistance of a cube having 1" sides.

Current density—The current density of a brush is based on the maximum of its continuous current capacity per square inch of cross section without glowing, honey-combing, undue heating, or sparking.

Glowing—A brush is said to glow when it becomes red or incandescent in spots. This is due to the short circuiting current under the brush, or the short circuiting combination with the working or load current.

Honey-combing—When brushes gradually burn away and form small craters in their faces, they are said to honey-comb. This is due to minute arcing action that is more or less of a hidden nature and may be of either a slow or rapid nature.

Hardness—Brushes have widely varying physical densities, some being very hard, others very soft. Hard brushes usually carry a large amount of abrasive and have a low current density or carrying capacity. Soft brushes are more highly graphite, carry abrasive to a limited extent only, and have higher current carrying capacity. The hardness or scleroscope reading is therefore indicative to a limited degree of the character of the brush.

Brush Inertia—This has to do with the weight of the brush. The lighter the brush, the more readily it will follow the irregularities of the commutator, and the more promptly it will respond to a given spring pressure.

Refractory—Any material which resists the ordinary methods of reduction is said to be refractory. A brush, therefore, which resists wholly or to a marked degree high temperatures such as the heat generated by an electric arc is said to be refractory.

Peripheral Speed—This is the speed in feet per minute of the commutator. Peripheral speeds which vary greatly, require brushes having different characteristics.

Brush Composition—Brush compositions consist of carbon, electrographite, and graphite.

1. Carbon is a non-metallic element found in all organic substances, and for commercial purposes in anthracite and other coals, and in charcoal. The amorphous or uncrystallized form includes charcoal, coke, lamp black, etc.

2. Electrographite (artificial graphite) is prepared commercially by heating coke, or other amorphous carbon in an electric furnace and converting it from a non-graphitic to a graphitic state.

3. Graphite (natural) also known as black lead and plumbago is a crystalline form of carbon. It is found in many forms and is widely distributed, Ceylon being perhaps the chief source of that used in commerce.

Combinations of any two or more of the above ingredients are mixed with or without abrasives and binders extruded or pressed into shapes varying from the sizes of the finished brush to blocks and slabs of many forms and dimensions, which are baked or burned for use as brushes. The blocks and slabs are subsequently sawed and ground into sizes to suit the market demands. Brushes may be ground to almost any shape and can be furnished in block shape, bare or copper-coated, drilled for or fitted with shunts, milled to the angle or radius to fit the commutator, fitted with caps to protect the tops from the pressure springs, and when necessary, equipped with brush lifting clips or devices.

The baking of the brush material is subject to many of the difficulties encountered in baking or firing earthenware. It is well known that a large piece of crockery or earthenware is more difficult to produce than a small piece, the reason for this being that there is more material and consequently, more likelihood of warping or cracking from uneven burning or firing. The same troubles occur with brush material. It is obvious, therefore, that brushes made from small blocks, bricks, or slabs of carbon, are more likely to prove uniformly good than brushes made from larger sizes of the same materials and mixtures.

A. I. & S. E. E. JUNIOR DIVISION

(Devoted to practical problems of electrical department employees in the Iron and Steel Industry)

Standard Testing Alternating Current Generators

In presenting this information taken from General Electric Company's testing manual, the Association of Iron and Steel Electrical Engineers feel that the man in the field may find many valuable suggestions that will aid him in his future problems in maintenance.

It is recommended that the Junior Member study this article carefully with the view of increasing his knowledge and efficiency in handling, operating and maintaining Alternating Current Generators.

Articles of this character and description will appear regularly in the columns of the Junior Membership Section of the Iron and Steel Engineer. *Editor.*

STANDARD TESTING ALTERNATING-CURRENT GENERATORS

The tests on alternating-current generators may be divided into four groups as follows:

Static Test
Short Commercial Tests
Long Commercial Tests
Complete Tests

STATIC TESTS

A static test includes the cold resistance of the field and armature, drop and polarity of the field, high-potential test on both field and armature, and record of air gap measurement.

SHORT COMMERCIAL TEST

A short commercial test on an alternating-current generator includes cold resistance measurement of both armature and field, drop and polarity of field, check and record of air gap measurement, saturation curve, phase balance, end play adjustment, shaft current, and phase rotation on polyphase machines.

Before starting the machine or applying any field excitation, the brushes on the collector rings should be sanded to insure a good contact surface and to avoid excess heating of the brushes or rings.

Saturation Curve

The saturation curve is taken in the same manner as described on page 457, October Iron & Steel Engineer. While taking this curve, voltage balance should be taken on all phases near the normal rated voltage of the machine.

A reading of commercial core loss should be taken while making the saturation curve. This is accomplished by reading the armature voltage and current, and the field voltage and current of the driving motor, without any excitation on the alternator. A similar set of readings is taken on the driving motor, with sufficient field excitation to give normal rated voltage on the armature of the alternator. The difference between the input to the driving motor for each set of readings will give the open-circuit core loss at normal voltage.

End Play Adjustment

The operation of properly adjusting the machine for end play has been described in a previous section. Oftentimes the machines are set up without their own shaft or bearings, and in such cases it is not necessary to make any adjustments unless the mag-

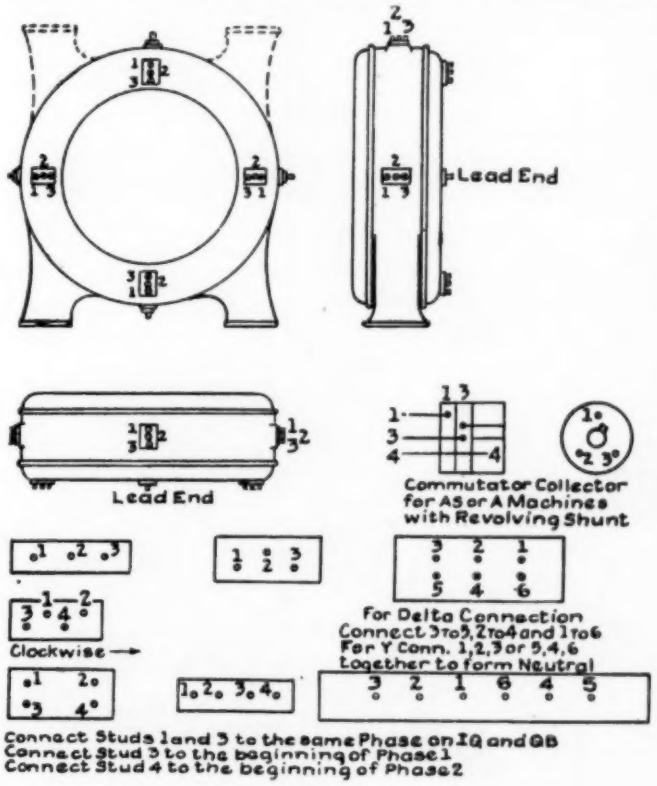
Lead End
Lead End
Commutator Collector for AS or A Machines with Revolving Shunt
For Delta Connection Connect 3 to 5, 2 to 4 and 1 to 6 For Y Conn. 1,2,3 or 5,4,6 together to form Neutral
Clockwise
Connect Studs 1 and 3 to the same Phase on 1Q and 6B
Connect Stud 3 to the beginning of Phase 1
Connect Stud 4 to the beginning of Phase 2

FIG. 1.
Connection Blocks

netic center is so far out that it causes excessive friction in the bearings.

Shaft Current

Shaft current is measured on smaller sizes of alternating-current machines. A magnetic leakage allows stray fields to occur, causing an e.m.f. to be induced in the shaft. In order to keep this e.m.f. from causing a current to flow from the shaft to the bearing and pitting the journal, one of the bearings is insulated, on the larger type machines. On the smaller machines, i. e., those below 500 kv-a., the magnitude of this e.m.f. ordinarily is not sufficient to cause any destructive action.

In order to insure that there are no currents flowing, a high reading a-c. ammeter should be connected to low resistance leads, one of which is in contact with the revolving shaft and the other fastened to the frame of the machine. If a reading is obtained on the instrument, the fact should be reported as a defect to be investigated. This procedure should not be followed on any machine that has an insulated bearing pedestal.

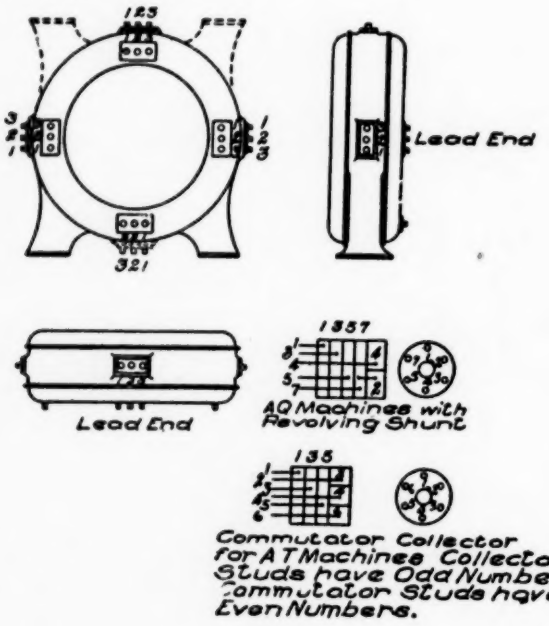

FIG. 2
Connection Blocks

Phase Rotation

Phase rotation should be taken on all polyphase machines using the phase rotation indicator.

A schematic diagram of a phase rotation indicator is shown in Fig. 3.

It consists of a laminated iron ring with four windings about 90 degrees apart.

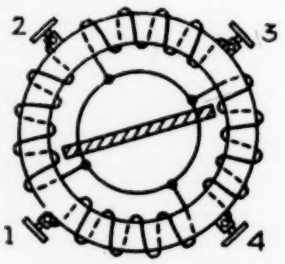

FIG. 3.
Phase Rotation Indicator

For two-phase circuits, all four windings are used, while for three-phase circuits, but three are used. The terminals are stamped 1, 2, 3, 4, and should be connected to the corresponding terminals on the alternating-current machine under test.

The phase rotation indicator revolves in a direction which indicates the order in which the e.m.f. reach their maximum value. When it revolves in a clockwise direction, the e.m.f. reach their maximum value in the order T1, T2, T3, T4, or T1, T2, T3, if only the three terminals are used. When it revolves in a counter-clockwise direction, the e.m.f. reach their maximum positive value in the reversed order. The order of the phases in alternating-current machines is such that the e.m.f. reach their maximum positive value in the order T1, T2, T3 for three-phase machines, and T1, T2, T3, T4 for two-phase machines for clock-wise rotation of the rotor from the connection end of the stator. For counter-clockwise rotation of the rotor, the order is reversed.

These indicators are intended to run from the residual magnetism of the larger machines. On the smaller machines it will generally be necessary to increase the voltage of the machine in order to operate the indicator. The minimum voltage at which the indicator will operate is 60 volts. The voltage should not be over 250 volts.

The terminals of the machine under test, whether three-phase or quarter-phase, should be connected to the corresponding terminals of the indicator. The indicator should operate on the residual voltage of the alternator, but if it will not, a small field current should be applied to the machine under test, and the voltage should gradually be brought up to a small amount. The magnet of the meter should revolve in the same direction as the rotor of the machine under test, when facing the connection end. The phase rotation indicator should operate on about 100 volts and should never be subjected to more than 150 volts. It is often necessary to start the magnet by hand. If it rotates in the opposite direction for a quarter-phase machine or a three-phase machine, either a phase is reversed or the wrong leads have been brought out. Figs. 1 and 2 cover every type of standard connection block, and will assist in the numbering of the machine terminals for the phase rotation indicator. If the block is on the side of the machine facing the bearing, or on the outside of the frame proper and at right angles to the shaft, the numbers should read 1, 2, 3 in a clockwise direction. If the block is in any other position, as on the side facing the bearing with the numbers running radially, or on the frame proper with the numbering parallel to the shaft, the same sequence of numbers should exist, but the block has been given a quarter turn in a clockwise direction. Each lead should be stamped with the number corresponding to one of the standard blocks. In the case of revolving armatures, the number is always from the outside ring toward the inner one.

LONG COMMERCIAL TESTS

A long commercial test includes all tests taken on a short commercial test, synchronous impedance, and heat runs.

Synchronous Impedance

The object of a synchronous impedance test is to determine the field current necessary to produce a

given armature current when the machine is running short-circuited. Since the regulation of the alternator is calculated from the impedance and saturation curves, care should be taken in order to obtain consistent results.

The armature should first be short-circuited through current transformers of suitable size, and then, with the machine running at normal speed, a field current should be applied sufficient to produce a good reading on the ammeters. Currents in all three phases should be measured, in order to see that the phases balance. If they do not balance, the trouble should be located before proceeding with tests.

When a balance is obtained, sufficient field should be applied to cause 150 per cent normal full load current to flow in the armature, and simultaneous readings taken of armature current, field current, and voltage. The field should then be diminished gradually, taking about six readings from 150 per cent armature current to 0 current, Plot a curve on the same sheet as the saturation curve, using field current as abscissae and armature current as ordinates. See Fig. 4.

When taking the synchronous impedance curve, a commercial core loss reading should be taken. Hold normal current on the machine under test and record the armature current and voltage, field current, and voltage of the driving motor. Then, with no field on the test machine, a similar set of readings should be taken on the driving motor. From these readings the short-circuit core loss can be calculated at normal load.

While taking the synchronous impedance curve, overload current should not be carried on the machine long enough to cause any injurious heating of the armature coils.

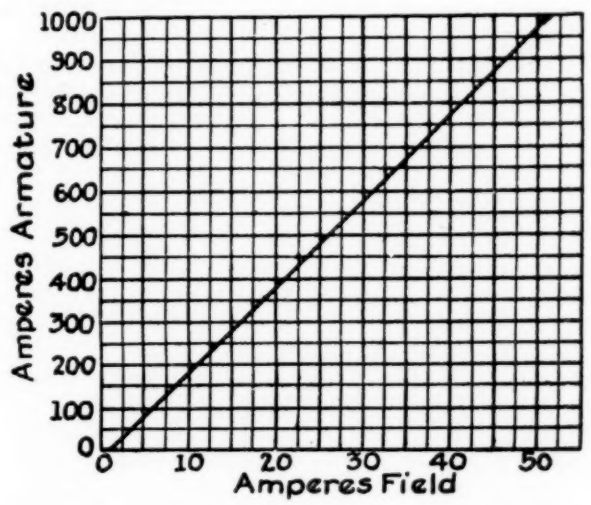

FIG. 4.
Synchronous Impedance Curves on a 500-kw., 600-volt, 360-r.p.m., 3-phase, 60-cycle, A-c. Generator

Heat Runs

The nature of the heat run given to the alternator depends upon its size and the facilities in the Testing Department for handling it. The different kinds of heat runs are described later on in this section.

COMPLETE TESTS

Complete tests on alternating-current generators consist of open-circuit core loss, short-circuited core loss, heat run, wave form, voltage regulation, and location of keyway, in addition to the tests mentioned under "Short Commercial Tests."

Open Circuit and Short Circuit Core Loss

Open and short circuit core losses have been described on Page 460, October, 1928, Iron & Steel Engineer.

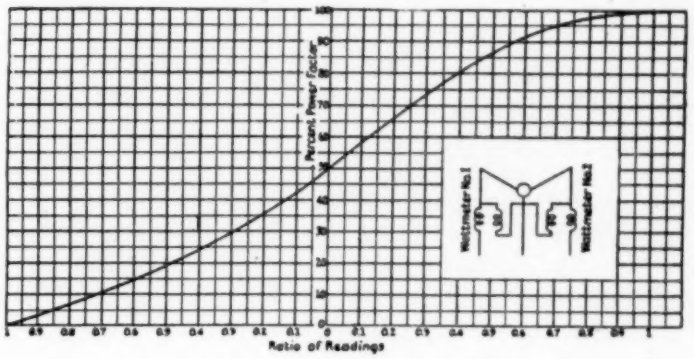

FIG. 5.
Power-factor on Wattmeter Readings on 3-phase Circuits

Heat Runs

Machines are oftentimes built so large that an actual operating load is difficult to obtain. In such cases, an equivalent load heat run is substituted. The heat runs then will be classified in two groups, the actual load heat run and the equivalent load heat run.

The Water Box Method

This method is similar to that described for direct-current generators, and may be used satisfactorily on small machines. It is an expensive process and should not be used if any other means can be provided, because the energy is thrown away. If the machine under test is wound for three-phase, the boxes should be connected in "Y." Care must be taken to keep the current in the various phases balanced. The leads of the generator should be connected to the blades of the boxes. If the water boxes will not stand the voltage of the machines, transformers must be inserted in order to step the voltage down to a value which the boxes will accommodate.

It is very often necessary to load the generator at a specified power-factor. If such is the case, a synchronous motor should be connected across the

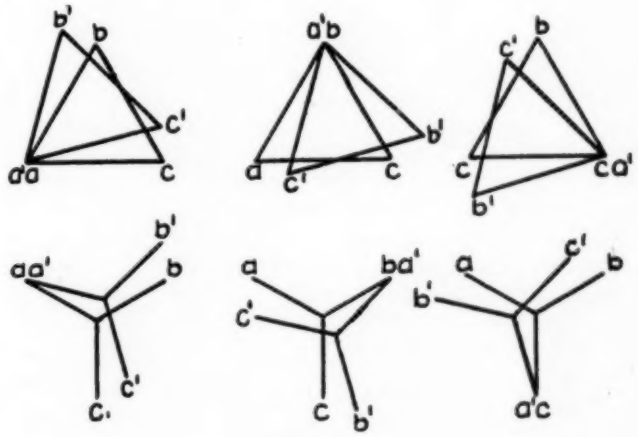

FIG. 6
Shifting of Phases Shown Diagrammatically

terminals of the machine under test and in multiple with the water boxes, having its field excited to give the required leading or lagging current in the armature of the machine being tested. If the generator is to be run with a leading power-factor, the field of the synchronous motor must be excited with a current above its normal excitation for unity power-factor. The machine under test is then run with a field below that for normal excitation. If a lagging power factor is required conditions are reversed. Wattmeters should be used to check the power-factor. The kv-a. output of the generator, multiplied by the power-factor, should equal the kw. input minus the losses in the driving unit and the test machine. For another check, the power-factor may be obtained by referring to the curve shown in Fig. 5. On this curve, per cent power-factor is plotted as ordinates and the ratio of the two wattmeter readings is plotted as abscissae. When both wattmeter readings are positive, the ratio is found on the right-hand side of the center line; when one reading is positive and the other negative, the ratio is found on the left-hand side of the center line. To obtain the specified power-factor, adjust the field on the test machine until the ratio of the wattmeter readings checks the ratio as shown on the curve for that particular power-factor.

Feeding-back Method

The larger size machines may be given an actual load heat run, when there are two machines of the same rating or nearly the same rating, by the feeding-back method.

The two machines used in this test must be direct connected and the losses may be either supplied mechanically or electrically. It is necessary to shift the stators with respect to each other so that the machines will remain continually out of phase with each other. The vector difference of the voltages thus generated by the two machines will cause a current to flow which may be varied by changing the relative positions of the stators. For example: Consider a three-phase machine, the phases of which are shown diagrammatically in Fig. 6. The machines should be run at rated frequency and wattmeters inserted in the line as a check on the power-factor. The fields should be excited to a value corresponding to the load at which it is desired to make the test. With points a and a′ connected together, the voltage across b and b′ should be read, the circuit closed, the value of the current flowing observed. Knowing the voltage between phases a-b, a′-b′ and between b and b′, the angle of phase displacement may be readily obtained. Should the armature current be considerably greater or less than that desired, a further trial will be necessary. Whenever a trial is made, the fields on either machine should be adjusted to give the approximate power-factor at which the machine is to operate, because a change in the power-factor affects the phase displacement of the machines.

The current value will vary nearly as the angle of displacement, so that an approximate value of the angle desired can be found from the value of current and angle previously ascertained. When the value of this angle has been determined, the phase displacement should be adjusted as nearly as possible to this value. This may be done as follows: With the machines still connected together as they were originally, the angle of phase displacement previously found will be increased 120 electrical degrees by connecting a′ and b. If a′ and c are connected, a still further displacement of 120 degrees is obtained. If with any of these connections, the field of one machine is reversed, a still further displacement of 180 degrees is made. With the connection which gives the nearest value of armature current to that required, a further displacement may be made by shifting the stator of one or both machines. Even with the angles of phase displacement possible with the various combinations of connections and field reversals, it may not be practicable to obtain the desired armature current. In this case, unbolt the coupling and shift the rotor of one machine around one or more bolt holes. The "cut and try" process should then be repeated.

Two frequency converters, consisting of a-c. generators and synchronous motors, may also be given an actual load run by shifting the phases of the generators or motors with respect to each other. The losses in the sets should be supplied electrically from the synchronous motor end. The stators of the generators or motors are usually held in cradles so that they may be rotated to run in phase with other machines; consequently, it is only necessary to turn the frames in their cradles to obtain the proper shift.

Zero Power-factor Heat Run

The best kind of an equivalent load heat run is a zero power-factor run or condenser run. The generator under test is run as a synchronous motor from some other alternator of equal size or larger. The field, of the machine under test, is then excited to a value greater than the unity power-factor value that will cause full load current to flow in the armature. It will oftentimes be necessary to reverse the excitation on the alternator from which power is supplied, in order to keep the voltage down to the normal value. Before starting the heat run, a no-load phase-characteristic should be taken. This is explained in the following section. After the heat run has been started, readings of armature current and voltage, field current and voltage, and speed, should be recorded at regular intervals, and the run continued until the temperatures become constant.

The Open-circuit Heat Run

Machines of large capacity or odd voltage and frequency are often given an open-circuit heat run. The generator is run with the armature open-circuited at a predetermined voltage which will give approximately the full load iron losses. This value is generally 110 per cent normal voltage. The run should be continued until the temperatures are constant, recording armature voltage and field current and voltage, with the speed held constant.

The Shirt-circuit Heat Run

A short-circuit heat run is always made in conjunction with an open-circuit run. The generator is run with the armature short-circuited at a predetermined current, usually 110 per cent normal rated current of the machine. This run, like the other, should be continued until the temperatures are constant, recording armature current and field current and voltage, with the speed held constant.

The Intermittent Heat Run

The intermittent heat run comes next to the power-factor run in determining the operating temperatures of the machine. This method is merely a

combination of an open and short-circuiting run, as the name implies.

The machine is first run for one-half hour under open-circuit conditions, with sufficient armature voltage to create a core loss equal to twice the core loss at the normal rated voltage of the machine. At the end of the half hour, the armature is short-circuited and an excitation on the field is held that will create an armature current equal to twice the I^2R and short-circuit core loss at normal rated current on the machine. At the end of the second half hour, the open-circuit condition is repeated. The machine is run alternately on open and short circuit until the temperatures on these circuits become constant. The time of alternation is then reduced to 15 minutes and this condition maintained until the open and short-circuit temperatures again become constant. Then the interval of alternation is reduced to 5 minutes and the run continued until the temperatures on the open and short circuit again become constant. The machine is then shut down and final temperatures taken.

An oil switch of sufficient capacity should be used to open and short circuit the armature.

Wave Shape

Wave shape is generally taken at no load by means of the oscillograph.

Voltage Regulation

Voltage regulation on an alternating-current generator is generally calculated from the saturation and impedance curves. In actually determining the regulation, the machine is subjected to normal load with normal voltage held on the armature. Then with the field excitation held constant, the load is suddenly thrown off and the armature voltage is noted. The difference between this voltage and the normal voltage, divided, by the normal voltage, is the per cent voltage of regulation.

It is impossible to load the larger sizes of machines, because of limited facilities. In such cases, the regulation is calculated

Location of Keyway

It is sometimes required that two machines which have their revolving parts on the same shaft, or which are to be directly connected, shall operate in series or multiple. In such cases the generated voltages must be in phase with each other. In order to make sure of this fact the keyways of the machines must be definitely located with respect to each other. This is done by connecting the field of the two machines in series and exciting them from the same source of power. The revolving parts are then adjusted and the keyways located so that, upon suddenly opening the field switch, no kick is obtained upon a voltmeter connected across any particular phase of either machine.

This position can best be determined in the following manner: Set the rotating part of the first machine with respect to the stationary part, so that no kick is obtained on a voltmeter connected across any one phase when the field circuit is suddenly opened. Then set the other machine, so that zero kick is obtained on that phase which is to be connected to the phase of the first machine on which zero kick was obtained. A definite marking should be made upon the machines so that the shop can cut the keyways in such a position that the relative position of the rotors will always remain the same.

Typical Steel Plant Electrical Department Spare Part Inventory

This Spare Part Inventory is shown here for comparison purposes only. No effort was made to secure the quantity of each individual item carried in stock, as that is a factor which is governed to a large extent by:

—A—Size of Plant
—B—Products Manufactured
—C—Geographical Location of Departments
—D—No. of Generators and Motors Installed
—E—Distance from Source of Supply
—F—Length in days of Turn Over
—G—Relation of Production to Capacity

This inventory covers a plant having Blast Furnaces, Open Hearths, Converters, Rolling Mills, and a large number of Finishing Mills. The plant has about 3,500 Motors installed.

Aluminum Bus Bars
Acid Sulphuric
Anchors, Steel Wing
Anchors, Ground
Annunciators
Arms, Wood Cross
Arresters, Lightning
Asbestos
Asbestos Wood
Arresters, Telephone
Ammeters, Portable
Ammeters, Switchboard
Bars, Flat Steel
Batteries, Dry Cell
Boxes, Joint
Boxes, Junction
Brackets, Wood
Blocks, Fuse
Brackets, Meter
Braid, Copper
Batteries, Storage
Bearings, Ball
Bearings, Roller
Bearings, Sleeve
Bells, Signal
Buzzers
Buttons, Push
Bolts, Carriage
Bolts, Galvanized
Bolts, Galvanized Eye
Boxes, Outlet 2" and ¾" Square and Oct.
Boxes, Switch (6 sizes)
Brass, Rolled
Brushes, Carbon Generator
Brushes, Carbon Motor
Brushes, Metallic Motor
Brushes, Carbon, Face Plate Controllers
Breakers, Air Circuit
Breakers, Oil Circuit
Buckets, Ore
Buckets, Coal Hoist
Buckets, Cinder
Bronze, Sheet
Bulbs, Tungar

Bushings, Conduit (½", ¾" (1, 1¼, 1½, 2, 2½, 3)
Bumpers, Crane
Blowers (See Fans)
Bushings, Porc. Wall
Brakes, Electric
Brakes, Mechanical

Cabs, Crane
Couplings, Flexible
Cutouts, Fuse (30 and 60 Amp.)
Cutouts, Thermal
Carbons (Blue Print Arc Lamp)
Canvas
Clevises, Insulators
Cloth, Tan Treated
Colorings, Lamp
Crossover, Trolley
Cutouts, Transformer
Chargers, Battery
Clamps, Guy Wire
Clamps, Trolley Wire
Clamps, Feeder Strain
Clamps, Bus Bar
Clamps, Dead End
Clamps, Pipe
Connectors, Wire (#0-2-4-6-8)
Coils, Choke
Copper, Bus Bar
Copper, Ribbon
Copper, (Rolled Rods)
Covers, Outlet Box (Round and Square)
Condulets
Covers, Condulets
Conduit, Metal (8 sizes ½" to 3")
Couplings, Metal Conduit
Caps, Metal Conduit
Conduit, Wireduct (See Loom)
Conduit, Fibre
Couplings, Fibre Conduit (8 sizes ½" to 3")
Conduit, Aluminum
Couplings, Aluminum Conduit
Collector Shoes
Cups, Grease
Cups, Oil
Circuit Testers
Cooper Fittings and Terminals
Clamps, Cable

Dressers, Commutator
Duck, Oiled Cloth
Duct (Square Conduit)

Fittings, Malleable Iron (7 sizes ¾" to 3")
Frogs, Trolley
Fans, Desk
Fans, Ventilating and Parts
Fibre, Sheet (10 sizes)
Fuses, cartridge (9 sizes)
Fuses, Plug (2 sizes)
Fuses, Knife Blade (5 sizes)
Flashlights
Fixtures, Lighting (Office)
Floodlights
Fittings, Switchboard Pipe
Fittings, Lamp Suspension
Fittings, Kondu
Fittings, Grease

Gears and Pinions, Cranes and Motors (115 sizes)
Guards, Wire Lamp
Governor, Elec. Air Compressor
Gongs, Crane
Gongs, Signal
Globes, Ball (for Lamps)
Groundlets
Grease, Light, Medium and Heavy
Gauges, Pressure
Guards, Safety (All Styles)
Glass, Window (Reinforced)

Hooks, Crane
Hooks, Guy
Holders, Wire
Hangers, Telephone Cable
Hangers, Thompson Lamp
Hangers, Conduit
Houseline (or Marlin Cord)
Holders, Lamp Shade
Horns, Signal
Hoists, Electric
Hangers, Fixture
Heating Units, Electric
Heaters, Roll Electric
Headlights, Locomotive

Insulators, Porcelain Pin Type
Insulators, Porc. Susp. Type
Insulators, Porclain Guy Wire
Insulators, Giant Strain
Insulators, Third Rail
Insulators, Tel Transmission
Insulators, Bus Support

Knobs, Porc. Split
Keys, Gear and Pinion

Lanterns, Signal
Ladders
Lining, Brake
Lamps, Mazda Clear
Locknuts, Conduit
Lamps, Frosted
Lamps, Colored
Lugs, Cooper Terminal
Locks (Switch Safety)
Loom

Magnets, Lifting
Matting, Rubber
Micarta Plate
Mica, Clear
Micanite, Flexible (2 sizes)
Micanite, Plate (6 sizes)
Meters, Power Factor
Meters, Watthour (Ind.)
Meters, Watthour (Recording)
Meters, Milli Volt
Meters, Milli Amp.
Meters, Boiler House
Meters, Vacuum
Meters, Steam
Meters, Portable
Magnetos

Nuts, Hex Steel (All Sizes)
Nuts, Hex Brass (All Sizes)
Ozite (Pothead Compound)
Oil, Transformer
Outlets, Convenience
Oil, Lubricating (Engine, Cylinder and Black)
Ohmmeters

Poles, Wood
Paper, Fish
Paper, Blotting (Filter)
Paste, Solder
Pins, Wood Insulator
Pins, Cotter
Pins, Metal Insulator
Plates, Flush Switch
Plates, Flush Receptacle
Plugs, Attachment
Posts, Inst. Binding
Plugs, Transformer Cutout
Paraffine
Panels, Safety
Pinions, Micarta
Pulleys (All Sizes)
Plugs, Flush Receptacle
Panels, Switchboard Slate
Panels, Switchboard Marble
Panels, Switchboar Composition
Powerlets

Rails, Cranes
Receptacles, Flush
Receptacles, Plug
Receptacles, Outlet Box Cover
Rosettes
Reducers, Lamp Socket
Rope, Wire (All Sizes)
Reels, Magnet Cable
Receptacles, Unit Type Plug
Rivets, Copper
Reflectors, Shallow Dome
Reflectors, Angle
Reducers, Speed
Rail Contacts and Supports

Sanders, Magnetic
Shafting, Cold Rolled
Shields, Expansion
Sirens, Electric
Solder
Studs, Hickey Fixture
Staples, Insulated
Steps, Wood Pole
Steps, Galv. Pole
Salts, Soldering
Splicers, Trolley Wire
Supports, Adjustable Insulator
Stones, Commutator
Signs, Danger
Sleeving, Cotton
Sleeving, Lead Cable
Supports, Bus Bar
Shunts, Ammeter
Sockets, Cast Hood Lamp
Sockets, Weatherproof
Sockets, Brass Key
Sockets, Switchboard
Sockets, Porcelain
Springs, Electric Brake
Spreaders, Crane
Shoes, Electric Brake
Switches, Flush Tumbler
Switches, Ammeters
Switches, Voltmeters
Switches, Snap
Switches, Pendent
Switches, Push Button, Flush
Switches, Wood Base Battery
Switches, Knife
Switches, Safety
Switches, Disconnecting
Switches, Push Button, Master
Soapstone
Screws, Steel Machine (All Sizes)
Screws, Brass Machine (All Sizes)
Screws, Cap
Synchronoscopes
Shellac, Orange Flake
Switches, Elevator Door
Switches, Float
Switches, Hatchway Limit
Slot Scrapers

Stops, Safety Limit (All Types)
Switches, Horn Gap

Tachometers
Thimbles, Wire Rope
Talc, Powdered
Terminals, Cable (Pothead)
Twine, Mason
Tape, Friction
Tape, Weatherproof, Ins.
Tape, Rubber Splicing
Tape, Cotton
Tape, Treated Cloth
Tape, Asbestos Paper
Tape, Asbestos Woven
Tape, Silks
Thermometer
Thermo-Couples
Transformers, Switchboard Current
Transformers, Switchboard Voltage
Transformers, Oil Ins.
Transformers, Bell Ringing
Tubing, Mica
Tubing, Fiber
Tubes, Porcelain
Tubing, Brass
Tubing, Copper
Turns, Metal Conduit
Turns, Fiber Conduit
Turns, Aluminum Conduit
Tools (for Machine Shop
Tools (for Armature Dept.)
Tools (for Millwrights)
Tools (for Linemen)

Undercutters, Commutator
Unilets
Unions (All Sizes)

VV Fittings
Varnish, Baking Insulating
Varnish, Air Drying
Valves, Solenoid Operated
Voltmeters, Portable
Voltmeters, Switchboard

Wax, Sealing
Washers, Lock
Washers, Galv. Round
Washers, Galv. Square
Washers, Fibre
Washers, Copper
Washers, Mica
Washers, Brass
Welder, Electric
Wheels, Track or Truck
Wheels, Trolley
Waste (Wool and Steel)
Waste, Cotton
Wire and Cables
Wire, Guy
Wire, Messenger
Wire, Hard Drawn Copper Telephone
Wire, Steel Banding
Wire, Bronze Spring
Wire, Rubber, Ins. Solid
Wire, Rubber Ins. Fixture
Wire, Rubber, Ins. Twisted Pair Telephone
Wire, Flameproof Jumper
Wire, Rubber, Ins. Pothead
Wire, Slow Burning Solid
Wire, Weatherproof Solid
Wire, DCC Rectangular Magnet
Wire, DCC Round Magnet
Wire, Magnet
Wire, Copper Trolley
Wire, Lead Fuse
Wire, Enameled Magnet
Wire, Copper Annunciator
Cable, Lead Covered Telephone

Cable, Bare Copper
Cable, Rubber Ins. Multi Conductor
Cable, Rubber Ins. Single Conductor
Cable, Varn. Camb. Ins.
Cable, Varn. Camb. Ins. Multi Conductor
Cable, Varn. Camb: Ins. Lead Covered
Cable, Weatherproof
Cord, Cotton Brd. Rub. Ins. Lamp
Cord, 2 Cond. Lamp Extension
Cable, Ext. Flex.
Cable, Hoisting (All Sizes)

Direct Current Motor, Spares for 147 Types and Sizes of Motors
Armatures, Direct Current Motor Spares
Armature Coils, Direct Current Motor Spares
Wiper Rings or Oil Guards
Finger Plates for Armature
Armature Spiders
Commutators, for 147 types and sizes of Motors
Mica V. Rings
Steel V. Rings
Armature Shafts
Pinion Nuts
Pinion Lock Washers
Series Field Coils
Shunt Field Coils
Commutating Coils
Terminals for Field Coils
Field Coil Springs
Field Coil Shields
Field Pole Pieces
Rubber Bushings for Field Leads
Wood Bushings for Field Leads
Brushholders, all Sizes and Types
Brush Holder Stems
Brush Holder Yokes
Armature Bearings
Armature Bearings Oil Rings
Axle Bearings
Axle Bearing Oil Rings
Bearing Caps
Bearing Housings
Bearing Brackets
Motor Frame Castings
Gear Guards
Axle Caps
Commutator Covers
Grease Box Covers
Motor Bed Plates
Motor Slide Rails

A.C. Motor Spares
Primary (Stator) Coils
Secondary (rotor) Coils
Collector Rings
Bearings
Brush Holders
Bearing Oil Rings

Drum Type Controller Spare Parts
Controlling Cylinders
Finger Bases
Finger Blocks
Arc Deflectors
Pole Piece Hinge Brackets
Soft Rubber Bushings for Cables
Caps for Top Controller
Water Caps
Cylinder Castings
Blowout Coils
Spacing Collars for Cylinder
Sheet Iron Collars
Contact Fingers
Operating Handles
Check Pawls
Pole Pieces
Contact Segments
Finger Tension Springs

Magnetic Type Controller Spare Parts
Magnetic Switch Contactors
Arc Shields
Flexible Shunts or Connectors
Contact Levers
Copper Contacts
Magnet Coils
Interlocking Contact Levers
Magnet Frames
Contact Lever Supports
Stationary Contact Supports
Armature Levers
Magnet Cores
Blowout Coils
Interlock Fingers
Adjusting Screws
Cap Screws
Arcing Contact Springs
Tension Spring, Interlock Finger
Top Supports
Washers, Cupped
Copper Contact Plates
Insuating Shields
Interlock Contact Posts
Arcing Horns
Copper Leaf Brushes

D.C. Relay Spares
Binding Posts
Series Coils
Contact Levers
Contact Tips
Contact Fingers
Contact Finger Supports
Blowout Coils
D.C. Overload Relays
Magnet Cores
Magnet Frames
Magnet Coils
Contact Lever Supports

Flat Face Controller Spares
Field Contacts—Copper
Armature Contacts—Copper
Dead Contacts—Brass
Dead Blocks—Fibre
Center Stops—Fibre
Carbon Contacts
Blowout Coils
Carbon Holders

Automatic Compensator Spares
Contact Tips
Aux. Contacts
Control Circuit Contacts
Series Relay Coils
Shunt Relay Coils
Braided Copper Connectors

Resistance Unit Spares
Tube Resistors
Cast Iron Grids
Grid Spacers

Insuating Spacers
Terminal Lugs

Miscellaneous
A.C. Starting Switches up to 10 HP Spares
Operating Coils
Transformer, Auto
Contacts
A.C. Enclosed Auto Motor Starters
A.C. Magnetic Contactors
Impedance Starters
Panel Type DC Automatic Starters
DC Auto. Mach. Tool Controllers, Non-Reversing
DC Aut. Mach. Tool Controllers, Reversing
Magnetic Switch Controllers for Lifting Magnets
Master Switch for Lifting Magnets
Traveling Cam Limit Devices

Items of Interest

Mr. Lane Johnson, Chief Engineer, United Engineering and Foundry Co., Pittsburgh, Pa., died Saturday, March 2, 1929. Mr. Johnson was ill only a few days with pneumonia. Lane Johnson was a national figure in Rolling Mill Practices; he was a member of the leading Engineering Societies in America, and he enjoyed a wide acquaintanceship in the Iron and Steel Industry.

Mr. Carl Taylor, Central District Manager Westinghouse Electric & Mfg. Co., has accepted the position of manager of the Refrigeration Dept., Westinghouse Elec. & Mfg. Co. Mr. Taylor will be located temporarily at Mansfield, Ohio.

Mr. L. R. Botsai, formerly manager of the Machinery Manufacturers' Division, has succeeded Mr. Taylor, and will be located soon in the new Grant Building, at Pittsburgh, Pa.

H. H. Wood, formerly chief engineer of the Laclede Steel Company of St. Louis, has joined the Industrial Department of The Timken Roller Bearing Company, Canton, Ohio. Mr. Wood will specialize in the application of Timken bearings to steel mill equipment of various sorts. For the present his headquarters will be in Canton.

The National Electric Products Corporation announce that Mr. C. C. Lafferty has been appointed Manager of the Cleveland territory with offices in Keith Building. Mr. Lafferty was formerly with Chicago-Jefferson Fuse Co.

The Metropolitan Device Corporation of Brooklyn, manufacturers of Murray Protective Devices, distribution equipment and Murray Electric Radiators, announces the appointment of Mr. William J. McIlvaine as General Sales Manager, effective February 15, 1929.

Mr. McIlvane comes to the Metropolitan Device Corporation from the Copperweld Steel Company with whom he served as District Sales Manager in charge of sales east of the Mississippi River. Mr. McIlvane served in the United States Navy during the war, going to the United Electric Light & Power Company of New York after his naval service, in the capacity of assistant to the Superintendent of Transmission and Distribution. From 1921 to 1925 he acted as District Manager for W. N. Matthews Corporation in New York, going to the Copperweld Steel Company in 1925.

NEW INSULATION REMOVING MACHINE

The Electric Service Supplies Company have placed on the market a new magnet wire insulation removing machine. The machine is self contained for floor mounting, being supplied with a cast iron pedestal, the revolving parts being properly guarded. Net weight of outfit complete is approximately 160 pounds.

NEW BOOKLET

The Standard Underground Cable Co., division of General Cable Corp., of Pittsburgh, have gotten out a new booklet on Jointing and Miscellaneous Materials. This 46 page Bulletin No. 741 will be sent to interested parties, on request.

THERMOSTATIC TUMBLER SWITCH

Trumbull Electric Company of Plainville, Conn., have gotten out a new Thermostatic Tumbler Switch. It is a small single pole switch for controlling fractional Horsepower Single phase motors. The Handle trips to "Off" position on an overload. To reset it is simply necessary to throw the handle "On" after the thermostatic metal has cooled. One of the most important features is, that the switch cannot be held "on" against an overload. Operating characteristics are similar to those of Thermal Overload Relays or Thermal Plugs. There is no Fusible Element which requires replacement. These switches are made in three types.

A NEW PRODUCT

A new product has been developed for steel armoring the surface of concrete or asphalt floors so that their life will be increased to many times the normal expectancy.

It is called "Floorgard," and is being placed on the market by Blaw Knox Company, which has pioneered such products as collapsible steel forms, batcher plants, one piece grating, and other innovations that soon turned out to be necessities.

Rapidly increasing traffic in plants the carrying of heavy loads on small-wheel trucks, the dropping of boxes, castings, and other heavy pieces soon breaks down the surface of the best constructed floor—and it is a difficult and expensive matter to re-surface a concrete floor.

There is now on the market a material for steel-armoring concrete, asphalt and composition floors so that the surface will be as strong as any part of the floor, and thus the useful life of the floor is prolonged to many times the normal expectancy of similar floors not so protected.

It is a built-up continuous steel mat that is laid down to form the surface of the floor. The pattern that it makes is not merely pleasing to look at—it is scientifically designed to present such a surface to traffic that stresses will be taken care of by the

steel itself, distributing loads throughout a wide area of floor. Furthermore, the design is such that that portion of the concrete appearing between the steel bars is in no way divided up into separate portions, but is "monolithic" with the rest of the concrete forming the floor body.

CASCADE TUNNEL LOCOMOTIVE MOTORS EQUIPPED WITH ROLLER BEARING ARMATURES

With the opening of the Great Northern's new eight mile tunnel through the Cascade Mountains many unique methods and applications of older methods have been brought out.

One of these unusual applications is the use of roller bearings on the motors of the electric locomotive that opened the tunnel and this new era in American railroading.

Each of the eight motors on this Baldwin-Westinghouse motor generator locomotive is equipped with Norma-Hoffmann roller bearings to carry its 3730 pound armature mounted on a six-inch shaft. This dimension together with the fact that the housing bore for the outer race is 12 inch diameter describes what is in fact one of the largest roller bearing installations for heavy duty. A ball bearing at one end takes care of shaft location. Norma-Hoffmann heavy duty type bearings are used, in view of the service required for hauling both freight and passenger traffic. In the passenger service the motor armatures may rotate at speeds up to 1450 r.p.m.

The eight motors have a combined horse power, one hour rating, of 4330 and a tractive effort of 112,500 pounds. This type of locomotive, for service on the electrified mountain division and through the longest tunnel in the Americas, is claimed to be the largest and most powerful in existence.

It is planned to use a pair of haul 2900-ton freight trains up either the eastern or western 2.2 per cent grades leading to the tunnel portals.

A 200-MILE WELDED PIPE LINE

A pipe line 205 miles long, running from Jal, New Mexico, to El Paso, Texas, is now being electrically welded. This pipe line, 16 inches in diameter, will carry gas for the El Paso Utilities Company, and is being installed by Smith Brothers, Inc., general contractors.

The electric arc welding of the entire pipe line is being done under the direction of Messrs. Fred Clark and F. G. Hoffman. A total of 27 General Electric welding equipments are in use, some mounted on Fordson tractors and driven by the tractor engine, and others mounted on trucks and trailers.

The pipe, in 30-foot sections, is strung along the cleared right-of-way. Seven of the 30-foot lengths are then lined up, making a section approximately 200 feet long. One welding crew fixes the sections temporarily in position by tack welding and another completes the welds.

The tack welding machines are self-propelled equipments, as the first welding crew is often some distance ahead of the men who complete the welding operation. The pipe is turned, as the welding progresses, by one man using lon-handled tongs. Every seventh joint is an expansion joint. This consists of a short piece of pipe with upset corrugations. This joint adds flexibility to the pipe as well as allowing for expansion and contraction when in use.

After the 200-foot sections are completed, another crew lines them up with the completed pipe line, using a caterpillar tractor and boom. As the pipe cannot now be turned, the welds are made by the "bell-hole" methods, in which the operator moves his own position to weld all sides of the pipe, making the weld on the lower side from an excavation dug beneath for that purpose.

By the use of 3/16 inch diameter welding electrode and a current of approximately 175 to 190 amperes, the greatest welding speed consistent with the highest quality weld is obtained. Each operator is able to make approximately 13 welds in ten hours.

After the final welding operation is completed, the joints are tested and then treated with a corrosion resisting compound, after which the pipe is lowered into the ditch.

NEW DEPARTURE MFG. CO.'S EXPANSION

One of the largest factory extension programs in the East this year is that announced by the New Departure Manufacturing Company of Bristol, Conn., makers of New Departure Ball Bearings. The new buildings will add 250,000 square feet of floor space to the main works at Bristol and approximately 80,000 square feet to the Meriden plant. The new addition to the Forge plant at Bristol has just been completed and added 25,000 square feet, so that the total of increased floor space within the year will reach the imposing figure of 355,200 square feet or slightly over eight acres.

When the new buildings are completed the total floor space of the plants at Bristol, Meriden and Hartford if placed in a one story building 40′ wide would extend away for about eleven miles. The new building at Bristol will be 404′ long by 128′ wide and will house the finish race grinding department, replacing the one story building of somewhat less floor area devoted to that purpose. At the Meriden plant the extension will be on the northeast side of the present factory and will be 220′ by 106′ in size, four stories high. This addition will house an extension of all manufacturing operations.

ORDER PLACED FOR ALUMINUM SHOP CRANE

The Alliance Machine Company, Alliance, O., has received an order from the Aluminum Company of America for a ten ton traveling shop crane, the main girders of which will be constructed from strong aluminum alloy. This use of aluminum will materially reduce the wheel load on the building and, it is expected, will also reduce operating costs.

Upon completion the aluminum crane will be installed in the new structural shape mill at the Aluminum Company's Massena Works. At the same time it is planned to install a duplicate of this crane built of steel in the blooming mill at Massena so that direct comparisons of operating expenses can be made.

The Timken Roller Bearing Co., of Canton, Ohio, are distributing a new book entitled "Wherever Wheels and Shafts Turn." It is a general description of Timken applications in the various industries. Copy will be sent on request.

ADVERTISING PAGES REMOVED

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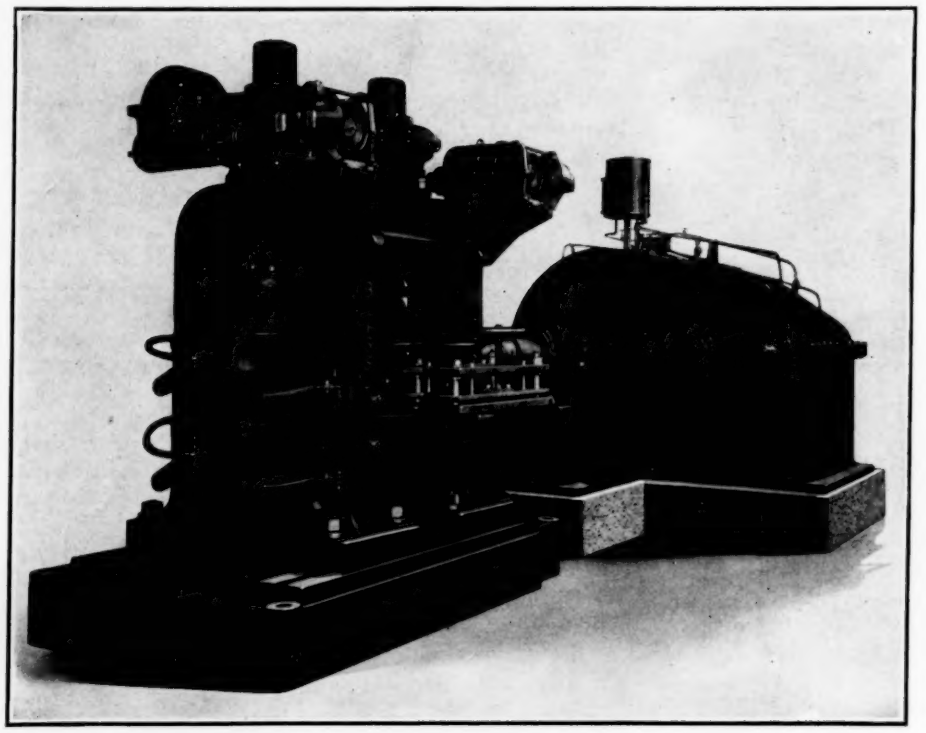

BLISS TWO-HIGH MILLS
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These mills are built in all sizes and roller-bearing equipped throughout.

Full details on request.

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